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## PROFESSOR GEIKIE'S CLASSIFICATION OF THE NORTH EUROPEAN GLACIAL DEPOSITS.

In Vol. III of this Journal, Professor James Geikie gives a concise account of his present ideas concerning the classification of the north European glacial formations. His statement involves a comparison of the drift formations of various north European localities with one another, and with those of the Alps. He differentiates six glacial epochs, separated by five interglacial epochs, which he names after typical localities, as follows:

First glacial epoch, Scanian.

First interglacial epoch, Norfolkian or *Elephas meridionalis* stage.

Second glacial epoch, Saxonian.

Second interglacial epoch, Helvetian or *Elephas antiquus* stage.

Third glacial epoch, Polandian.

Third interglacial epoch, Neudeckian.

Fourth glacial epoch, Mecklenburgian.

Fourth interglacial epoch, Lower Forestian.

Fifth glacial epoch, Lower Turbarian.

Fifth interglacial epoch, Upper Forestian.

Sixth glacial epoch, Upper Turbarian.

1. *Scanian stage.*—The oldest glacial formation of north Europe appears in Schonen and points to a Baltic glacier. In England perhaps the Chillesford Clay and Weybourn Crag with

their arctic molluscan fauna belong to this stage. Here also Geikie places the oldest Alpine glacial deposits as well as the old "Diluvium" of the plateau of central France. In another part of his work he expresses the opinion that the oldest ground moraine in the Baltic region of Germany belongs to this stage.

2. *Norfolkian.*—To this stage belongs the Forest bed of Norfolk, during the formation of which a climate prevailed at least as temperate as that of today. In Alpine districts the lignite of Leffe and elsewhere, as well as the interglacial deposits of the Hötting breccia, indicating a climate warmer than that of the present day, correspond to this stage.

3. *Saxonian.*—In this epoch the ice reached its greatest expansion. In north Europe the formations of this epoch extend to the borders of the Carpathians, the Sudetic Mountains, the Erzgebirge and the Thuringian Mountains. In the Alps, the corresponding formation covers a more extensive area than that of the Scanian epoch, while in Great Britain the corresponding sheet of drift is more widespread than that of any preceding or following epoch. To this stage belongs the lower bowlder clay of the British Isles, the Lower Diluvium of Holland and north Germany, the outer moraines and the associated gravels of Alpine lands, as well as the older moraines of the numerous mountain chains of middle and southern Europe.

4. *Helvetian.*—The character of the flora and fauna is variable, being here more arctic and there more temperate. To this stage belongs the interglacial deposits in Lanarkshire, Ayrshire, Edinburghshire, etc., and the Hessle gravels of East Anglia, the beach deposits of Sussex, and certain cave accumulations of mammalian remains, the interglacial beds of Holstein and Kottbus, the sands of Rixdorf, the interglacial beds of Moscow the interglacial deposits of Cantal, as well as numerous old river deposits of the Thames, Seine, Rhine, etc.

5. *Polandian.*—To this stage belong the glacial and fluvioglacial deposits of a Scandinavian *mer de glace*, which was smaller than the second, and the similar deposits of Great

Britain, the Alps and other districts. This stage includes the upper bowlder clay of the British Islands, the Upper Diluvium of central north Germany, Poland and central west Russia, the ground and terminal moraines of the "inner zone" of the Alps, together with the attendant gravels, and the younger valley moraines in various mountain chains.

6. *Neudeckian.*—The deposits of this interglacial stage are best observed in the southern coast lands of the Baltic. They originated partly in salt, and partly in fresh water, and are intercalated between two ground moraines, which are designated the lower and upper bowlder clay respectively. The fauna points to a temperate, not to an arctic climate.

7. *Mecklenburgian.*—To this stage belong the ground moraines and end-moraines of the latest Baltic glacier, and it reaches its southern extremity in the terminal moraine of the Baltic *Höhenrücken.* Of the same age as these north German deposits (Upper Diluvium of northern north Germany) are the moraines of the first postglacial stage in the Alps, the great valley glaciers of the British Islands, the Yoldia deposits of Scandinavia, the 100-foot beach of Scotland with its arctic fauna, and certain arctic plant beds below the Turbaries of Great Britain, Denmark and Scandinavia.

8. *Lower Forestian.*—To this stage belong the deposits of the large fresh water lake (Ancylus-beds) filling a part of the basin of the Baltic, the older buried forests under the peat bogs of northwest Europe, and to some extent the Scandinavian Littorina beds. In the Alps no equivalent is known. The land in Europe possessed at that time a greater extent and a warmer climate than at the present day.

9. *Lower Turbarian.*—Marked by expansion of the sea, moister and colder climate, glacial formations in Scotland and Norway, where some of the valley glaciers extended to the sea, though most terminated at a considerable distance from it. In the Alps, the deposits of the second postglacial stage, the moraines situated in the inner valleys, correspond to this stage. This stage is represented in Britain by certain peat beds, in

Scandinavia by calcareous tufa, and certain Littorina beds and in Scotland by beach lines.

10. *Upper Forestian.*—In northwestern Europe a second forest bed, overlying 8, represents this stage. The area of land is greater than in the preceding glacial stage, but is still less then in the preceding interglacial epoch. The flora and fauna indicate a temperate climate drier than that of the 9th stage.

11. *Upper Turbarian.*—Characterized by a new advance of the sea on the land. The shores are no longer reached by the ice, but it is highly probable that the moraines in the upper parts of the valleys of Scotland and Norway, and belonging to the last glacial period, are of the same age as the lower beach lines. With the close of this glacial epoch recent conditions begin.

This is the new scheme by which Geikie would correlate the whole of the European glacial deposits, The following is given in tabular form, for the sake of simplicity.

| Stage. | Great Britain. | Scandinavia. | Alps. | North Germany. |
|---|---|---|---|---|
| 1. | Chillesford clay. Weybourn crag. | Deposits of the oldest Baltic glaciers in Schonen. | Oldest ground-moraine of the Baltic. | *Deckenschotter* and moraines belonging to it. |
| 2. | Forest-bed of Norfolk. | | | Lignite of Leffe. Hötting breccia. |
| 3. | Lower Bowlder clay. | Moraines and fluvio-glacial formations. | Lower Diluvium. | Outer moraine. High terrace gravels. |
| 4. | Marine deposits of Lanarkshire, Ayrshire, etc.; Hessle gravel, beach deposits of Sussex. | | | Peat bed in Holstein and Lignites of Switzerland and Altgau near Kottbus. Sands of Rixdorf. |
| 5. | Upper bowlder clay. | | Inner moraine and lower terrace gravels. | Upper Diluvium south of the Baltic terminal moraine. |

| Stage. | Great Britain. | Scandinavia. | Alps. | North Germany. |
|---|---|---|---|---|
| 6. | | | | Marine deposits in West Prussia. |
| 7. | Valley glaciers and 100-foot beach of Scotland. | Yoldia clay. | Moraines of the first post-glacial stage. | Upper Diluvium north of the Baltic terminal moraine. |
| 8. | Lower forest-bed. | Ancylus beds, Littorina beds (in part). | | |
| 9. | Terminal moraines in the valleys. | Littorina beds (in part). | Moraines of the second post-glacial stage. | |
| 10. | Upper forest bed. | | | |
| 11. | Terminal moraines in the upper parts of the valleys. | | | |

The high authority of Professor Geikie on all questions concerning the European Ice Age has caused this classification, of the correctness of which Geikie himself is not thoroughly assured, to be received and used as final by many German writers who are not in a position thoroughly to appreciate the significance of the questions involved. Thus R. Credner[1] writes:

Folgen wir den Anschauungen, zu welchen neuerlich einer der hervorragendsten Glacialgeologen James Geikie, auf Grund vergleichender Untersuchungen sämmtlicher europäischer Vergletscherungsgebiete, vor Allem der britischen, der alpinen und der skandinavischen, gelangt ist, so haben wir für unser baltisches Becken vier durch Interglacialzeiten von einander getrennte Eisausbreitungen anzunehmen; und . . . . es entstand schliesslich, den Rand des letzten baltischen Eisstromes andeutend, der Zug echter Endmoränen, welcher in Gestalt wallartig gestalteter Blockschüttungen nordischen Ursprunges von Preussen bis nach Schleswig-Holstein hinein den Landrücken krönt.

In opposition to the preceding, and in full concert with my colleague in the Royal Prussian Geological Survey, who with me is

[1] Entstehung der Ostsee, pp. 540 and 646.

concerned in the geological exploration and mapping of the north German plain, I am bound to say that the fourfold classification of the north German glacial formations, given by Geikie, in no way corresponds to our observations, nor to the statements published in the "Explanations to the geological special map of Prussia and the Thuringian states," or in the annual report of the Royal Prussian Geological Survey, and in other places. After many years of careful work in the territory referred to, we find no conclusive reason for ascribing the ground moraine, designated by us as the upper bowlder clay, to more than one ice epoch. On the contrary, all of my colleagues who are or were occupied in the territory of the terminal moraine of the Baltic range, are, like myself, firmly of the opinion that the youngest ground moraine in front of and behind the terminal moraine, was deposited at one and the same time, by one and the same *mer de glace* distinct from and younger than that which deposited the upper bowlder clay of the territory of middle north Germany.

I must next consider the reasons which guided Geikie in his reference of the Upper Diluvium (drift) of north Germany to two glacial periods. They are stated in the second edition of the *Great Ice Age*, and seem to me to be essentially traceable to the four following points of view :

1. In different localities the ground moraine of the epoch of most extensive glaciation (Saxonian stage) contains (on account of the different directions of movement, radiating from the north of Scandinavia) bowlders quite different from the ground moraine of the younger inland *mer de glace*, which moved in the direction of the Baltic. According to Zeise the lower ground moraine of Schleswig-Holstein, is, so far as concerns its constitution, in no way different from the lower ground moraine of the moraine district, so the former cannot be the equivalent of the lower bowlder clay of the Mark, Posen, etc.

2. In Finland two systems of glacial striæ are developed ; an older one, which thus far has been observed only outside the territory enclosed by the terminal moraine, and a younger one

which thus far has been observed only inside the territory enclosed by the terminal moraine. The latter owes its formation to a glacier which moved in the direction of the Baltic, and which cannot have exceeded the line occupied by the terminal moraine. The ground moraines before and behind this moraine must belong to two different ice epochs.

3. The upper bowlder clay of Great Britain contains Scandinavian bowlders, and the Scandinavian *mer de glace*, in this third ice epoch came in contact with the Scottish one. But the ice depositing the Upper Diluvium of the Cimbric peninsula did not quite reach the North Sea; therefore this Upper Diluvium cannot be of the same age as the Scottish Diluvium of the third ice period, but must belong to a later fourth ice period. We come now to a comparison, if we suppose that the terminal moraine of the Baltic range represents the outermost edge of an independent glaciation, differing in point of time from that left behind by the Upper Diluvium of middle north Germany.

4. The separation is also shown by the appearance of the interglacial formations at Neudeck in West Prussia.

On the other hand we must remark (1) that continual study of bowlders in the different ground moraines has convinced German geologists, more and more, that no fundamental difference in this respect, is to be found; that, in other words, no single stone can be considered as a guide stone of the ground moraine of a definite ice epoch throughout the whole of its duration. Therefore we must form no far reaching conclusion from the local differences between bowlders belonging to two ground moraines lying one over the other.

2. Geikie believes that the Finnish terminal moraine is identical in point of time with that of the Baltic range. The line of union which he draws from east Prussia to Finland is, to my knowledge, purely hypothetical, and supported by no observations. I look for the easterly continuation of the Baltic terminal moraine much farther south, in the interior of Russia, and am of the opinion that the Finnish terminal moraine belongs with that

of middle Sweden and southern Norway, a view which is shared by Herr Vogt in Christiania.

3. It seems to me unnecessary entirely to repudiate the opinions of the north-German geologists in order to explain the occurrence of Scandinavian bowlders in the upper bowlder clay of Great Britian. It remains also to be proved that these Scandinavian bowlders have not been taken from the terminal moraines of the second ice period and incorporated in the drift of the third, and it may also be questioned whether the ground moraine of Scotland with northern bowlders really belongs altogether to the third glacial period, or whether the connection of the Scandinavian with the Scottish ice in the third glacial period is more than imaginary. I am prompted to raise these questions, because there are extremely weighty reasons against the acceptation of the Baltic terminal moraine as the outermost extremity of a separate (fourth) glacial epoch. On the contrary, the similarity in age of this moraine with the so-called upper bowlder clay of the Mark, Posen, etc., seems undisputed. I will state these reasons more definitely.

Of the terminal moraine of the Mark-Brandenburg, seventy-five square kilometers have been carefully mapped (scale 1 : 25,000) by the geological survey, and the investigation and surveying of the bordering territory on both sides reaches almost to Stettiner Haff in the north, and nearly to the northern edge of Lausitz in the south; therefore the territory investigated stretches in round numbers seventy-five kilometers from the terminal moraine in both directions. I have myself mapped a strip of country in the territory of the Baltic range between the Oder and Vistula extending thirty-four kilometers from east to west, and 100 kilometers from north to south. The terminal moraine passes through this strip for a distance of forty-five kilometers, and a territory twelve to twenty-four kilometers in breadth south of the terminal moraine is included within it. I have also by general surveying of the 500 kilometers of terminal moraine between the Oder and the Vistula, crossed the range in many places. All this work, and particularly the special mapping of about

150 field sheets (1 : 25,000) has now shown that the uppermost bowlder clay north and south of the terminal moraine are identical, that they belong to one glacial epoch, and that one sees in the terminal moraine[1] not the external margin, but only a stage of retreat of the latest glacier of these countries. In numerous places the ground moraine passes smoothly under the terminal moraine and in this manner several bridges are formed between the inner and outer ground moraine, and their identity is so firmly established, that stronger arguments than Geikie's are required to overturn the results of long years of careful, special inquiry. Those parts of the ground moraine passing under the terminal moraine are joined together in large masses to the north and south with the extensive ground moraines which Geikie maintains belong to two different ice epochs.

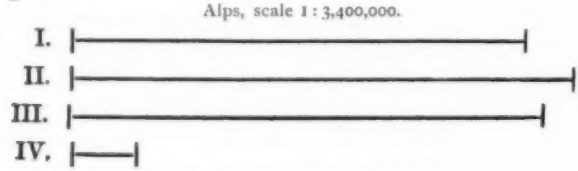
4. By mentioning as proof of his position, the existence of marine interglacial formations at Neudeck in West Prussia, Giekie plainly reaches a false conclusion, for he assumes what has still to be proven, that the last ground moraine but one of Neudeck is of the same age as the last (uppermost) ground moraine south of the Baltic. Without this proof the marine layers of Neudeck have no demonstrative significance, especially as their underlying beds are not known, and no observations have been made as to the number of ground moraines beneath them. Granted, however, that Geikie's view is right, that the Baltic terminal moraine is the southern limit of a distinct glaciation, one cannot understand why each of the other terminal moraines of north Germany may not also represent the edge of the ice during a distinct glacial period. On this basis the so-called "last glacial epoch" would have to be divided into four if not five epochs, so that even the most fanatical advocate for as many glacial periods as possible would be terrified.

I see a farther argument against Geikie's classification in the great difficulties of his comparison and in the inequality of the layers placed in the same stage. While with regard to the older

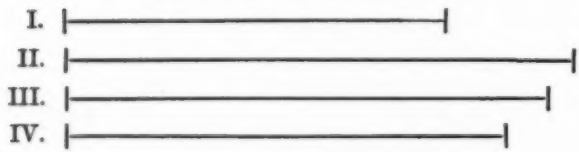
[1] I think Dr. Keilhack here uses "terminal moraine" in the German, not in the American sense (see p. 136 this number of this JOURNAL). R. D. S.

glacial periods there is a satisfactory conformity between the ice expansions of Great Britain and those of north Europe and the Alps, such conformity is altogether wanting in Geikie's assumed fourth epoch. The Baltic glacier supposed by him to belong to the fourth period is still of such immense size, and is so little inferior to those of the earlier epochs, that it is almost impossible to correlate it with the valley glaciers of the Alps which Penck has described, and it seems to me with perfect right, as representing only postglacial episodes. Hensen has regarded the similar deposits of Norway as epiglacial projections of existing glaciers. A graphic representation, such as that of Fig. 1 shows better than words can, the unnaturalness of Geikie's classification. If we suppose the expansion of the north European and Alpine glaciations to be expressed by lines which represent the extent of glaciation from the northern end of the Gulf of Bothnia, and from the central Alps respectively, and if the lines which represent the greatest extremity of ice be represented by unity in both cases, we obtain the proportions expressed by the following figures:

Alps, scale 1 : 3,400,000.




North Europe, scale 1 : 23,500,000.




If, however, one considers the Baltic terminal moraine as well as all others which lie further south, only as stages in the retreat of a single ice-sheet, as the Prussian Geological Survey has done, and so unites Geikie's No. 3 and No. 4 into No. 3, all difficulties of comparison at once disappear. 1, 2 and 3, in north

Europe correspond respectively with 1, 2 and 3 in the Alps, and the small extension of ice in the fourth and fifth ice epochs, recognizable in the Alps, Norway, and Scotland, and of approximately equal extent, are represented in north Germany, not by the reappearance of a *mer de glace*, but by climatic depressions only.

On the other hand I can agree with Geikie in his view that the principal glacial period (Saxonian stage) is the second glacial epoch, which had a predecessor in the so-called Scanian stage. The undeniable proof of three extensive glaciations of the Alps must awaken the suspicion that the north European glacial period also possesses a threefold division, and this suspicion would be increased still more in the mind of the present writer, by a number of other phenomena. The reason, however, why the special surveying has so far produced no conclusive evidence of a pre-Saxonian glacial period, lies simply in the fact that the mapping has been confined almost exclusively to districts in which no ground moraines of the inland ice of the Scanian stage exists, but where the deposits of this epoch are almost exclusively fluvio-glacial, and these for the most part fine. It is known, morever, that such formations in north Germany found due appreciation much later than those in the Alps, and that today even eminent geologists, such as H. Credner, will not acknowledge that they possess any demonstrative power. What has led me to recognize in the lower sands and clays of the Diluvium of middle north Germany the fluvio-glacial equivalent of a glacial period older than that which deposited the lower bowlder clay of the Mark, is the fact that between these layers are to be found a flora and fauna which point to a mild, temperate climate like that of today, if not indeed a warmer one. Because, however, the underlying layers contain certain northern material, such as feldspar, fragments of bryozoans, flints, and occasionally even large bowlders, the conclusion is not to be gainsaid that the ice lay at no very great distance from the territories in which those northern sands were deposited. The superimposed layers, however, contain a forest vegetation with deciduous trees, a water vegetation with plants of southerly

character, such as Trapa natans, and even Cratopleura. Such, however, can never thrive in a flat country, if the latter is partly covered with glacier ice and the climate of that country arctic. Therefore a period with a warm climate must necessarily have existed between the deposition of the oldest northern sands and those of the ground moraine of the lower bowlder clay, and therefore for north Germany a third oldest period must be assumed besides the two glacial periods which deposited the upper and lower bowlder clay. The ground moraines of this oldest glacial period I recognize not only in Schonen, but also in the deepest ground moraines of the Baltic range, especially in that part of it lying to the east of the Oder. On the other hand, no observations have hitherto been made which point to an extension of these ground moraines in the district south of the range.

If I attempt at the conclusion of these remarks, which I consider necessary for the verification and defense of the standpoint adopted in the official survey in north Germany, to give a classification of the north German diluvial deposits in tabular form, I beg that this attempt may be considered only as a private opinion, which I should like to submit to a wider circle, for criticism and examination.

*Preglacial.*— Not yet determined with certainty. No deposits between the Miocene and the first glacial epoch certainly recognized.

*First glacial epoch.*— Oldest ground moraines in the region of the east Baltic Lake district. Fluvio-glacial formations, reaching to Hanover, and the southern part of the Mark, *e. g.*, the sands under the deposits of the first interglacial period.

*First interglacial epoch.*— Clays and marls rich in Paludina (Paludina deposits) in the understratum of Berlin. Peat of Klinge near Kottbus. Fresh water lime of the Flaming (Belzig, Görzke, Ziesar) and of the heath of Lüneberg. Diatomaceous layers of the Soltau, Oberohe and Rathenow. Yoldia clay in West Prussia, Cyprina clay in Holstein, fauna of Burg in western Holstein, Cardium sands of Lauenburg, etc.

*Second glacial epoch.*— Lower bowlder clay of north Germany. Red bowlder clay of the Altmark; numerous fluvio-glacial sands and clay (Glindower clay) under and over it.

*Second interglacial epoch.*— Mammalian fauna of Rixdorf, marine and fresh water deposits of west and east Prussia, oyster-banks of Slade, Blankanese, Fahrenkrug; peat of Lauenburg, Beldorf, Fahrenkrug, and elsewhere. Calcareous tufas of Madgeburg, fresh water formations of Rathenow and the district of Potsdam.

*Third glacial epoch.*— Upper bowlder clay of north Germany. Terminal moraines of the Baltic Range and more southerly districts. Valley sands of the great valleys and ice-dammed seas. Clayey deposits (valley clay, *Deckthon*).

*Postglacial epoch.*— Arctic flora beyond the north German Turbaries.

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## THE AVERAGE SPECIFIC GRAVITY OF METEORITES.

In order to determine for purposes of hypothesis the density of a body formed by the aggregation of a multitude of meteorites, it is desirable first to learn the average specific gravity of those which have thus far fallen to the earth.

The writer is aware of but one attempt, the results of which have been published, to determine this quantity in a general way. These results are given in a paper by Rev. E. Hill in the Geological Magazine for 1885.[1] From Flight's "Chapters on Meteorites" this writer obtained the specific gravities of sixty-five different masses. The addition of these and division by 65 gave 4.84 as an average specific gravity. As this result took no account of the weights of the specimens, however, a recalculation was made from those whose weights and specific gravities were known, and an average of 5.71 obtained. As this sum again, however, included the great Cranbourne meteorite, whose weight of 3½ tons far exceeded that of all the rest, all masses over 250 pounds in weight were excluded. From the 52 cases thus averaged, a specific gravity of 4.58 was obtained.

Another method of arriving at the desired result was based on the ratio of metallic to stony meteorites, as they occur in the British Museum collection. This ratio is 205 stony to 55 metallic meteorites. Separating according to this ratio the 57 cases referred to, an average specific gravity of 4.55 was obtained.

R. P. Greg has also[2] found the specific gravity of about 70 stony meteorites to be 3.4. He says, however, that "as those possessing the smallest specific gravity are necessarily the most destructible and fragile, and after meteoric explosion less likely to arrive on the surface of the earth in an entire or tangible state, we may very fairly take their average density nearer the

[1] New Series, Decade III, Vol. II, p. 516.

[2] London Phil. Mag., 4th Series, Vol. VIII, p. 337.

mean of these two extremes, say, 3.0." As this density is intermediate between that of Mars, 5.3, and Jupiter, 1.4, he considers it as confirming the theory that meteorites belong to the series of planets, and have their orbits at a greater mean distance than that of the earth's from the sun.

A careful consideration of the results above quoted makes it difficult to accept any of them as final. The chief objection to Hill's results lies in the fact that there can be no assurance that the 57 cases which were listed by Flight, represented the average constitution of meteoric matter. Only an average obtained from the largest number of cases possible can be considered trustworthy, even though such an inquiry involve, as Hill states, "enormous labor of research." Again, it should be borne in mind that all the data which can at best be obtained, form but a small part of the whole, so that it is desirable that the relation of this part to the whole should be determined as accurately as possible. Daubree has calculated[1] that the fall of a meteorite on some portion of the earth is a phenomenon of daily occurrence, yet the number of *observed* falls during the past century has averaged not over one for every four months. This gap between possible and observed falls, due, of course, to the fact that a large portion of the earth's surface is covered by water, or is uninhabited by persons capable of intelligent observation, makes the collection of as large a number of data in regard to observed falls as possible, desirable.

It is only, however, during the present century that any systematic record of meteorite falls has been made at all. To include specimens preserved from earlier falls, is, therefore, likely to weaken rather than strengthen the probability of accuracy in the average.

Again, it seems incorrect to include any meteoric "finds" in obtaining data for the desired average. The stony meteorites, owing to the oxidation of the metallic grains which they contain, and the easy decomposability of olivine and others of their mineral

[1]Annales des Mines, 1868.

constituents, disintegrate and decay far more rapidly than the metallic. The metallic meteorites are, therefore, likely to be found long after stony ones of their time have gone to decay. The unusual weight of the metallic meteorites, moreover, and the silvery appearance of their interior, often lead to their being picked up and preserved where the stony meteorites escape observation. That the metallic meteorites are much more likely to be found than the stony, is indicated by the fact that of 263 meteorite "finds" now preserved in collections, 205 are wholly metallic, 28 largely so and only 30 are stony. To determine the average specific gravity of meteoric matter by striking an average of meteorites preserved in collections, seems, therefore, manifestly incorrect.

The amount of the correction which, according, to Greg should be made for meteoric matter that does not reach the earth in an entire or tangible state, must be at best a matter of speculation. I am of the opinion that the amount of such meteoric dust which reaches the earth is small, for few traces of it have ever been found. Since its amount is probably small and its specific gravity can only be guessed, I have thought it safe to omit it altogether from the calculation.

Considering, then, the desirability of using as many data as possible while at the same time excluding all that might be misleading, I can think of no better method of arriving at the desired result than to determine the average specific gravity of the meteorites observed to fall during the past one hundred years, this being the period within which a fairly complete record of meteorite falls has been kept. Such a method, will, of course, exclude a large number of metallic meteorites with high specific gravity, for only seven, or at most eight, of these have been known to fall within the past century. But it is not unreasonable to suppose that these may represent the proportion of iron to stone falls in all periods of the earth's history; for, as has been stated, the iron meteorites found may have endured for many centuries, while the stony ones of similar epochs have gone to decay.

Greg[1] has considered the proportion of stone to iron falls to

[1] London Phil. Mag., 4th Ser., Vol. VIII, p. 453.

be 25 to 1, *i. e.*, that 96 per cent. of all meteorites that fall consist of stony matter. Hence it may be assumed that, for 34 iron masses, for example, found, 25 times as many or 850 stone falls have taken place.[1] The ratio deduced from the falls of the last century would be somewhat higher than this, viz., 40 to 1. There is, therefore, strong reason for belief that there is normally a great excess of stone over iron falls. The alternative supposition, which has been urged by some, is that metallic falls have been more abundant during earlier periods of the earth's history than now, but there is no proof that these were not accompanied by a similar proportion of stone falls to that which now prevails.

If it be granted that the desired average can best be obtained from the observed falls of the past century, then again there must be recognized the fact that data for calculation on this basis suffer serious limitations owing to the lack of records of the specific gravity and weight of many of the falls. The specific gravity, so far as known, of most of the falls up to 1860, can be found in Buchner's catalogue,[2] but since that time analysts have been lamentably negligent in giving specific gravities in their published descriptions of meteorites. In searching for weights of falls too, one finds great scarcity of data, the records of earlier falls being most at fault in this respect. But though the amount of data obtainable is comparatively small, enough is at hand to permit conclusions of value.

Brezina's latest catalogue[3] gives 298 falls as having taken place since the Wold Cottage fall of 1795. For 175, or more than one-half of these, I have been able to find specific gravities given in some one or more of the records. These range between 1.70 for Alais to 7.84 for Cabin Creek, but by far the larger number lie between 3 and 4 in specific gravity. The average obtained from these 175 cases is 3.65.

[1] There is evidently a clerical error in his statement that 96 times as many, or 3624 stone falls may have taken place.

[2] Die Meteoriten in Sammlungen, Dr. Otto Buchner, Leipzig, 1863.

[3] Annalen der K. K. Naturhistorisches Hof Museum, Band X, Heft 3 und 4, Vienna, 1896.

As noted by Hill, however, an accurate result can only be obtained by taking into account the weights of the specimens, since a number of small weights of high or low specific gravity would considerably raise or lower an average obtained from individual specific gravities, while their effect on the density of a mass made up of large weights of nearly uniform specific gravity would be insignificant.

Unfortunately, a calculation on this basis reduces somewhat the number of cases from which an average can be drawn, since in many of the cases where specific gravity is given, no record of the weight of the meteorites can be obtained. By considerable searching, however, I have been able to obtain records of 142 falls, the specific gravity and weights of which are known. These include, fortunately, all but one of the metallic meteorites and most of the larger falls, such as Weston, Juvenas, New Concord, Estherville, Mocs, Alfianello and Winnebago county. By reducing these weights to the unit of water, adding and dividing, an average of 3.69 is obtained for the whole, a result nearly in accord with that deduced from the specific gravities alone.

It is possible that from records of a larger number of falls, a slightly different average might result, but it seems fair to assume that the difference would not be more than .2 or .3 from the figures given. Until further data are at hand, therefore, the value of 3.69 may be regarded a fair one for the average specific gravity of the meteoric matter which has come to the earth within the period of intelligent human observation.

To determine the probable density of a body formed by the aggregation of such matter is not a part of the purpose of this article, for this involves elaborate considerations of the effects of pressure. The present investigation has at least shown how desirable it is that those who in the future publish descriptions of meteorites should take pains to determine the specific gravity and weight of each fall. The accurate statement of these will be of great service in further investigation.

OLIVER C. FARRINGTON.

# DRIFT PHENOMENA IN THE VICINITY OF DEVIL'S LAKE AND BARABOO, WISCONSIN.[1]

THE study of the drift about Devil's Lake and Baraboo, Wisconsin, has brought out facts and relations of more than local interest, which it is the aim of this paper to state.

*Location.*—The region is in the central part of the southern half of the state, about thirty-five miles northwest of Madison, and on the western limit of the area covered by the Green Bay lobe of the last great ice-sheet—the ice-sheet which deposited the Wisconsin drift. Since the ice of this epoch advanced as far to the west in this region as that of any earlier epoch, the region concerned is also on the border between the glaciated country to the east, and the driftless area to the west.

*General topographic relations.*—The accompanying map, Fig. 1, shows the surroundings of the region especially concerned, and Fig. 2 the topography of a small area about Devil's Lake. Extending in a general east-west direction and rising 500 feet to 800 feet above the surrounding country, is the great Baraboo quartzite range (shaded area Fig. 1) in which Devil's Lake (*a*) is situated. This range, and especially the larger range to the south, is the most prominent topographic feature of the region, and, as will be seen, had not a little influence on the behavior of the ice at its margin. Devil's Lake divides the range into an eastern and a western portion, known respectively as the east and west bluffs (or ranges). The highest point of the range, about four miles east of the lake, has an altitude of 1620 feet. The eastward extension of the west range (see Fig.

[1]This paper is based on work done in connection with the field course in geology in The University of Chicago. Other students than those whose names appear in connection with this article, had something to do with the development of the facts here set forth. This is especially true of Messrs. H. R. Caraway, E. C. Perisho, D. P. Nicholson, L. Wolff and O. J. Arnold.

2), lying south of the lake, and popularly known as the "Devil's Nose," has an elevation of 1500 feet.

North of the main range there is a lesser ridge of quartzite, more or less interrupted, rising 300 feet to 500 feet above the

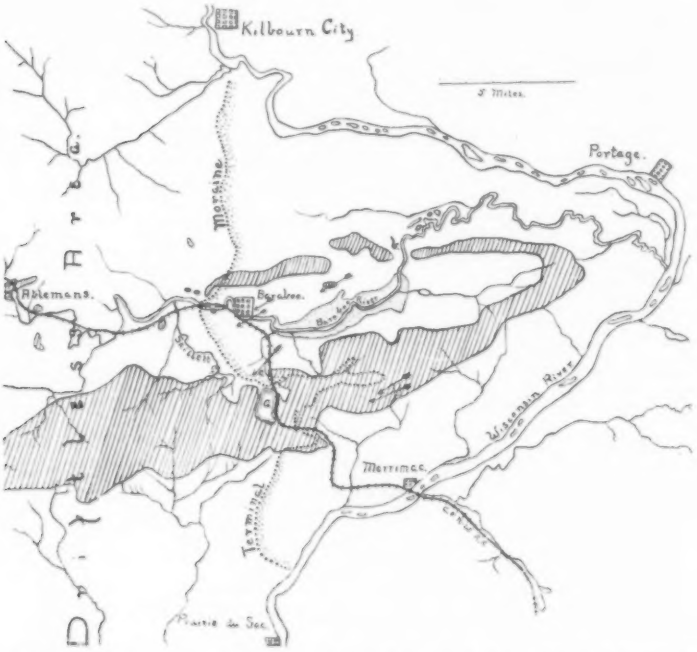


FIG. 1. Map of the area about Baraboo and Devil's Lake. The shaded area is quartzite. The unshaded area is underlain by Potsdam sandstone.

Baraboo River, and reaching its greatest prominence at the "Lower Narrows" of that stream (*b*, Fig. 1). Between these quartzite ranges is the capacious valley, partly filled with drift, through which the Baraboo River flows.

About the quartzite ranges, and within the area covered by the ice, the surface is marked by those varied features which usually affect the surface of a region heavily covered with drift.

West of the limit of the ice, the topography is equally characteristic of the driftless area, though modified along the flats by the deposits of the glacial drainage.

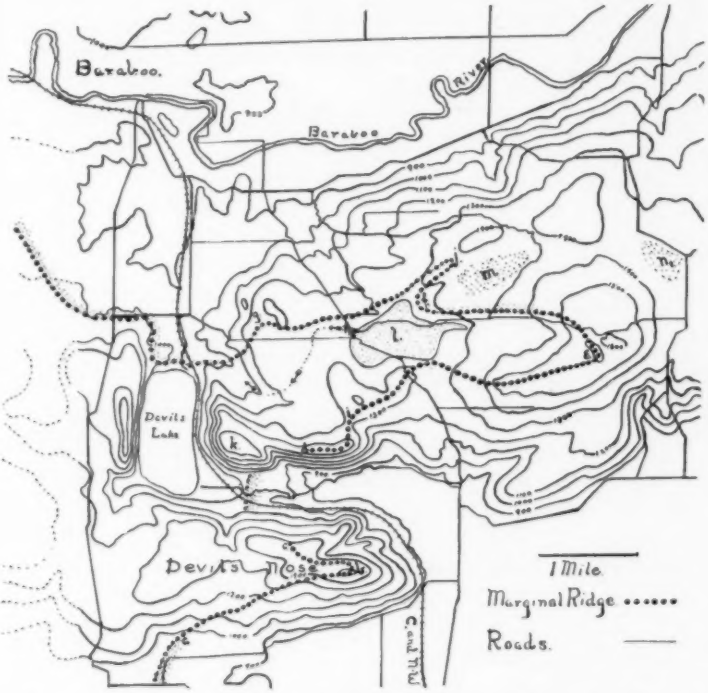


FIG. 2. Topographic map (contour interval 100') of a small area about Devil's Lake, taken from the Baraboo sheet of the U. S. Geological Survey. The dotted western continuations of the contours represent extensions of the contours beyond the published map.

*Ice movement.*—From the course of the striæ, it is known that, as the ice advanced into this region, its general direction of motion was west-southwest. This is in accord with the general direction of movement in the western portion of the Green Bay lobe. The location and direction of recorded striæ appear

on the map shown in Fig. 1. With but one exception they vary from W. 20° S. to W. 30° S. The exceptional direction, W. 60° S., is found on the north side of the main quartzite range (*c*, Fig. 1), where the normal deploying of the ice was prevented by the steep face of the bluff. It illustrates the tendency of glacier ice to move in a direction essentially at right angles to its margin.

*The terminal moraine.*—The limit of the ice advance is marked by a well defined terminal moraine, the outer margin of which west of the Wisconsin River is shown on the accompanying map (Fig. 1). Swinging southward from Kilbourn City in in gentle curves, it turns westward in the great valley between the quartsite ranges, and then loops back to the east along the north face of the quartzite range *nearly seven miles* before crossing it. Across the crest of this range it turns promptly to the west in the valley between the east range and the Devil's Nose. About the elevation which bears this name, the moraine again loops back to the east, and after rounding the "Nose" turns promptly to the west. After following this direction for about two miles, it turns southward, reaching the Wisconsin River about seven miles below Merrimac.

On the low lands, the terminal moraine has the characteristics which usually affect such formations. In width it varies from half to three-quarters of a mile. Approached from the west, that is, from the driftless side, it is a somewhat prominent topographic feature, often appearing as a ridge thirty, forty or even fifty feet in height. Approached from the opposite direction it is notably less prominent, and its inner limit, wherever located, is a more or less arbitrary line. Beyond its notably irregular course, the terminal moraine on the low lands about the quartzite ranges possesses no unusual features. A deep, fresh cut southeast of the lake illustrates its complexity of structure, a complexity which is probably no greater than that of terminal moraines at many points where less well exposed. The section is represented in Fig. 3. The stratified sand to the right preserves even the ripple marks which it received when deposited. To the left, at the same

level, there is a body of till over which is a bed of stoneless and apparently structureless clay. In a depression just above the clay, with till both to the right and left, is a body of loam which possesses the normal characteristics of loess, both as to constitution and structure. It also contains calcareous concretions, but no shells are found.

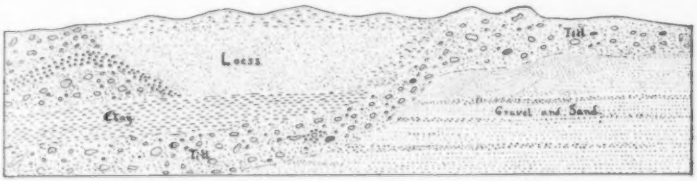


FIG. 3. Section of the moraine southeast of Devil's Lake, as exposed in a railway cut (1896).

Away from the ridges the outer face of the moraine from Kilbourn City to Prairie du Sac is bordered by overwash plains, or morainic aprons, in their normal positions and relations, except that in one locality just west of Barbaoo and south of the river, the moraine edge of the overwash plain is built up even with the crest of the moraine itself.

*The margin of the ice across the quartzite range.*—In tracing the moraine over the greater quartzite range, it is found to possess a unique feature in the form of a narrow but sharply defined ridge of drift, formed at the extreme margin of the ice at the time of its maximum advance. For fully eleven miles, with but one decided break, and two short stretches where its development is not strong, this unique marginal ridge separates the drift-covered country on the one hand, from the driftless area on the other. In its course the ridge lies now on slopes, and now on summits, but in both situations preserves its identify. Where it rests on a plain, or nearly plain surface, its width at base varies from six to fifteen rods, and its average height is from twenty to thirty feet. Its crest is narrow, often no more than a single rod. Where it lies on a slope, it is asymmetrical in cross section (see Fig. 4), the

shorter slope having a vertical range of ten to thirty-five feet, and its longer a range of forty to one hundred feet. This asymmetrical form persists throughout all that portion of the ridge which lies on an inclined surface, the slope of which does not correspond with the direction of the moraine. Where it lies on a flat surface, or an inclined surface the slope of which corresponds in direction with the course of the ridge itself, its cross section

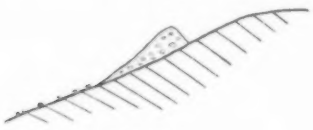

FIG. 4

FIG. 5

FIG. 4. Diagrammatic cross section of the marginal ridge as it occurs on the south slope of the Devil's Nose. The slope below, though glaciated, is nearly free from drift.

FIG. 5. Diagrammatic cross section of the marginal ridge as it appears when its base is not a sloping surface.

is more nearly symmetrical (see Fig. 5). In all essential characteristics this marginal ridge corresponds with the *End-Moräne* of the Germans.

For the sake of bringing out some of its especially significant features, the ridge may be traced in detail, commencing on the south side of the west range. Where the moraine leaves the lowlands south of the Devil's Nose, and begins the ascent of the prominence, the marginal ridge first appears at about the 940-foot contour (*a* Fig. 2). Though at first its development is not strong, few rods have been passed before its crest is fifteen to twenty feet above the driftless area immediately to the north (see Fig. 4) and from forty to one hundred feet above its base to the south, down the slope. In general the ridge becomes more distinct with increasing elevation, and except for two or three narrow post-glacial erosion breaks, is continuous to the very summit at the end of the Nose (*b* Fig. 2). The ridge in fact constitutes the uppermost forty or forty-five feet of the crest of the Nose, which is the highest point of the west range within the

area shown on the map. Throughout the whole of this course the marginal ridge lies on the south slope of the Nose, and has the asymmetrical cross section shown in Fig. 4; above (north of) the ridge at most points not a bowlder of drift occurs. So sharply is its outer (north) margin defined, that at many points it is possible to locate it within the space of less than a yard.

At the crest of the Nose (*b* Fig. 2) the marginal ridge, without a break, swings northward, and in less than a quarter of a mile turns again to the west. Bearing to the north it presently reaches (at *c*) the edge of the precipitous bluff, bordering the great valley at the south end of the lake. Between the two arms of the loop thus formed, the surface of the Nose is so nearly level that it could have offered no notable opposition to the progress of the ice, and yet it failed to be covered by it.

In the valley between the east bluff and the Nose, the terminal moraine lies further west than on the elevations. The ice moved against the Nose from the east, and mounted to its highest point, but in this achievement it so far spent its strength as to be unable to continue, even over the comparatively level surface beyond. Divided by the Nose as by a wedge, it moved westward over the lower land on either side, but failed to occupy the intervening crest of the ridge.

In the great valley between the Nose and the east bluff, the marginal ridge does not appear. In the bottom of the valley the moraine takes on its normal form, and the slopes of the quartzite ridges on either hand are much too steep to allow any body of drift, or loose material of any sort, to lodge on them.

Ascending the east bluff a little east of the point where the drift ridge drops off the west bluff, the ridge is again found (at *d*) in characteristic development. For some distance it is located at the edge of the precipitous south face of the bluff. Farther on it bears to the north, and soon crosses a col (*i*) in the ridge, building it up many feet above the level of the bed rock. Here again, as on the Nose, the ice that had surmounted the elevation had spent its strength and was unable to move forward, even though forward movement would have been down grade.

From this point eastward for about three miles the ridge is clearly defined, the slopes about equal on either side, and the crest as nearly even as the typography of the underlying surface permits. The topographic relations in this part of the course are shown in Fig. 5.

At *e* (Fig. 2) this marginal ridge attains its maximum elevation, 1620 feet. Here again, the ice having surmounted this great elevation, the greatest of the region, was unable to move forward down the slope, although it had had energy enough to climb fully 300 feet in the last mile of its advance.

At this great elevation, the ridge turns sharply to the northwest at an angle of more than 90°. Following this direction for little more than half a mile, it turns to the west. At some points in this vicinity the ridge assumes the normal morainic habit, but this is true for short distances only. Further west, at *f*, it turns abruptly to the northeast and is sharply defined. It here loops about a narrow area less than sixty rods wide, and over half a mile in length, the sharpest loop in its whole course. The driftless tract enclosed by the arms of this loop is lower than the drift ridge on either hand. The ice on either side would need to have advanced no more than thirty rods to have covered the whole of it.

From the minor loop just mentioned, the marginal ridge is continued westward, being well developed for about a mile and a half. At this point the moraine swings south to the north end of Devil's Lake, loses the unique marginal ridge which has characterized its outer edge across the quartzite range for so many miles, and assumes the topography normal to terminal moraines. At no other point in the United States, so far as known to the writers, is there so sharply marked a marginal ridge associated with the terminal moraine, for so long a distance.

From Fig. 1 it will be seen that the moraine as a whole makes a great loop to the eastward in crossing the quartzite range. From the detailed description just given of the course of the marginal ridge, it will be seen that it has three distinct loops; one on the Devil's Nose (west of *b*, Fig. 2); one on the main

ridge (west of *e*) and a minor one on the north side of the last (southwest of *j*). The first and third are but minor irregularities on the sides of the great loop, the head of which is at *e*.

The significant fact in connection with these irregularities in the margin of the moraine is that each loop stands in the lee of a prominence. The meaning of this relation is at once patent. The great quartzite range was a barrier to the advance of the ice. Acting as a wedge, it caused a reëntrant in the advancing margin of the glacier. The extent and position of the reëntrant is shown by the course of the moraine in Fig. 1. Thus the great loop in the moraine, the head of which is at *e*, (Fig. 2) was caused by the quartzite range itself.

The minor loops on the sides of the major are to be explained on the same principle. Northeast of the minor loop on the north side of the larger one (*j*, Fig. 2) there are two considerable hills, reaching an elevation of nearly 1500 feet. Though the ice advancing from the east-northeast overrode them, they must have acted like a wedge, to divide it into lobes. The ice which reached their summits had spent its energy in so doing, and was unable to move forward down the slope ahead, and the thicker bodies of ice which passed on either side of them, failed to unite in their lee. The application of the same principle to the loop on the Devil's Nose is evident.[1]

*Constitution of the marginal ridge.*—The material in the marginal ridge, as seen where erosion has exposed it, is till, abnormal, if at all, only in the large percentage of widely transported bowlders which it contains. This is especially true of the surface, where 90 per cent. of the large bowlders are in some places of very distant origin, and that in spite of the fact that the ice which deposited them had just risen up over a steep slope of quartzite, which could easily have yielded abundant bowlders. In other places the proportion of foreign bowlders is small, no more than one in ten. In general, however, bowlders of distant origin predominate over those derived close at hand.

[1] It is at k, Fig. 2 that the preglacial gravel referred to in Vol. III (pp. 655–67) of this JOURNAL is found.

*The slope of the upper surface of the ice at the margin.*—The marginal ridge on the south slope of Devil's Nose leads to an inference of special interest. Its course lies along the south slope of the Nose, from its summit on the east to its base on the west. Throughout this course the ridge marks with exactness the position of the edge of the ice at the time of its maximum advance, and its crest must therefore represent the slope of the upper surface of the ice at its margin.

The western end of the ridge *a* (Fig. 2) has an altitude of 940 feet, and its eastern end *b* is just above the 1500-foot contour. The distance from the one point to the other is one and three-fourths miles, and the difference in elevation, 560 feet. These figures show that the slope of the ice along the south face of this bluff was about 320 feet per mile. This, so far as known, is the first determination of the slope of the edge of the continental ice sheet *at its extreme margin.* It is to be especially noted that these figures are for the extreme edge of the ice only. The angle of slope back from the edge was doubtless much less.

*Devil's Lake.*—At the north end of Devil's Lake, and again in the capacious valley leading east from its south end, there are massive terminal moraines. Followed southward, this valley leads off toward the Wisconsin River, and is probably the course of a large preglacial stream. It is now occupied by a small tributary to the Wisconsin, the head of which is separated from the lake by the massive moraine. To the north of the lake, the head of a tributary of the Baraboo comes within eighty rods of the lake, but again the terminal moraine intervenes. From data derived from wells it is known that the drift both at the north and south ends of the lake extends many feet below the level of its water, and at the north end, the base of the drift is known to be at least fifty feet below the level of the bottom of the lake. The draining of Devil's Lake to the Baraboo River is prevented only by the drift dam at its northern end. It is nearly certain also, that, were the moraine dam at the south end of the lake removed, all the water would flow out to the Wisconsin, though the data for the demonstration of this conclusion are not to be had. There

can be no doubt that the gorge between the east and west bluffs was originally the work of a pre-Cambrian stream, though the depth of the pre-Cambrian valley may not have been so great as that of the present. Later, the valley was filled with the Cambrian (Potsdam) sandstone,[1] and reëxcavated in post-Cambrian and preglacial time. Devil's Lake then occupies an unfilled portion of an old river valley, isolated by great morainic dams from its surface continuations on either hand. Between the dams, water has accumulated and formed the lake.

While the ice was at its maximum stand, it rose above the moraine dams at either end of the lake. The melting of the ice supplied abundant water, and the water of the lake stood above its present level. The height which it attained is not known, but it is known to have risen at least sixty-five feet higher than now. This is proved by the presence of a few drift bowlders lodged on the west bluff at this height. They represent the work of a berg or of bergs which at some stage floated out into the lake.

*The preglacial stream flowing through the Devil's Lake gorge.*— The great gorge in the quartzite bluffs, a part of which is occupied by the lake, was a narrows in the preglacial valley. If the Baraboo was the stream which flowed through this gorge, the comparable narrows in the north quartzite range — the Lower Narrows of the Baraboo — is to be accounted for. The stream which occupied one of these gorges probably occupied the other, for they are in every way comparable except in that one has been modified by glacial action, while the other has not.

The Baraboo River flows through a gorge — the Upper Narrows — in the north quartzite range at Ablemans, nine miles west of Baraboo. This gorge is much narrower than either the Lower Narrows or the Devil's Lake gorge, suggesting the work of a lesser stream. It seems on the whole probable, as suggested by Irving,[2] that the Wisconsin River in preglacial time, flowed south

[1] This fact was made known by IRVING, Geology of Wisconsin, Vol. II. Irving also advanced the explanation here given, of the lake.

[2] Loc. cit., p. 508.

through what is now the Lower Narrows of the Baraboo, thence through the Devil's Lake gorge to its present valley to the south. If this be true, the Baraboo must at that time have joined this larger stream at some point east of the city of the same name.

*Extinct glacial lake on the east quartzite bluff.*—Between the arms of the main terminal moraine loop on the quartzite range, about two miles east of Devil's Lake, is a notable flat. Its location and extent are shown in Fig. 2 (*l*). With the exception of the north side, and a narrow opening at the northwest corner, the flat is surrounded by high lands. When the ice occupied the region, its edge held the position shown by the line marking the limit of its advance, and constituted an ice barrier to the north.[1] The area of the flat was, therefore, almost shut in, the only outlet being a narrow one at *h*, Fig. 2. Excavations in the flat show that it is covered with stratified sands, gravels, and clays of glacial origin, to a depth of at least sixty-five feet. If this filling were removed, the bottom of the area would be much lower than at present, and it is evident that when the ice had taken its position along the north side of the flat, an enclosed basin must have existed. Into this basin water from the melting ice flowed, forming a lake. At first it had no outlet, and the water rose to the level of the lowest point (*h*, Fig. 2) in the rim of the basin, and thence overflowed to the west. Meanwhile the sediments borne in by the glacial drainage were being deposited in the lake in the form of a subaqueous overwash plain, the coarser parts being left near the shore, while the finer were carried further out. Continued drainage from the ice continued to bring sediment into the lake, and the subaqueous overwash plain extended its delta-like front farther and farther into the lake, until its basin was completely filled. With the filling of the basin the lake became extinct. Further drainage from the ice followed the line of the outlet, the level of which corresponds with the level of the filled lake basin. This little extinct lake is of interest as an

[1] The moraine line on the map represents the crest of the marginal ridge rather than its outer limit, which is slightly nearer the lake margin. Stratified drift of the nature of overwash also intervenes at points between the moraine and the lake border.

example of a glacial lake which became extinct by having its basin filled during glacial times, by sediments washed out from the ice.

Near the northwest corner of this flat, an exposure in the sediments of the old lake bed shows the curiously contorted

FIG. 6. Contorted layers of sand and silt, in the bed of the extinct glacial lake.

layers of sand, silt, and clay represented in Fig. 6. The layers shown in the figure are but a few feet below the level of the flat which marks the site of the lake. It will be seen that the contorted layers are between two series of horizontal ones. The material throughout the section is made up of fine-grained sands and clays, well assorted. That these particular layers should have been so much disturbed, while those below and above remained horizontal, is strange enough. The grounding of an iceberg on the surface before the overlying layers were deposited, or the action of lake ice may have been responsible for the singular phenomenon.

*Skillett Creek.*—Skirting the morainic apron or overwash plain southwest of Baraboo, is a little stream, tributary to the Baraboo, known as Skillett Creek. For some distance from its head (*a* to

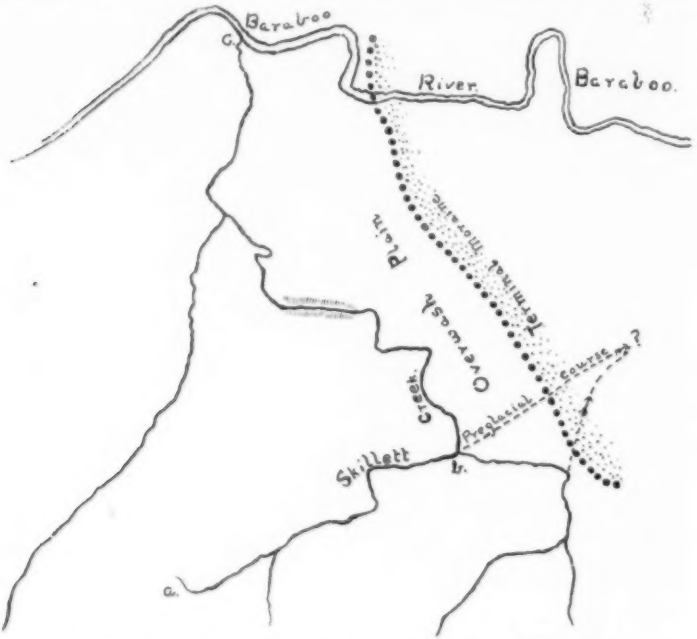


FIG. 7. Skillett Creek, illustrating the points mentioned in the text.

*b*, Fig. 7) its course is through a capacious preglacial valley. The lower part of this valley was filled with the water-laid drift of the overwash plain. On reaching the overwash plain the creek therefore shifted its course so as to follow the border of that plain, and along this route, irrespective of material, it has cut a new channel to the Baraboo. The postglacial portion of the valley (*b* to *c*) is everywhere narrow, and especially so where cut in sandstone.

The course and relations of this stream suggest the following explanation: Before the ice came into the region, Skillett Creek

probably flowed in a general northeasterly direction to the Baraboo, through a valley comparable in size to the preglacial part of the present valley. As the ice advanced, the lower part of this valley was occupied by it, and the creek was compelled to seek a new course. The only course open to it was to the north, just west of the advancing ice, and, shifting westward as fast as the ice advanced, it abandoned altogether its former lower course. Drainage from the ice then carried out and deposited beyond the same, great quantities of gravel and sand, making the overwash plain. This forced the stream still further west, until it finally reached its present position across a sandstone ridge or plain, much higher than its former course. Into this sandstone it has since cut a notable gorge, a good illustration of a postglacial valley. The series of changes shown by this creek is illustrative of the changes undergone by streams in similar situations and relations all along the margin of the ice.

*Damming of the Baraboo.*—West of the terminal moraine on either side of the Baraboo River are broad flats, extending at least as far up the stream as Ablemans. At various points, exposures show the material of the flat to be laminated clay of lacustrine type. The tributaries to the Baraboo in this region are bordered by similar flats composed of similar material. These flats, together with the flats along the main stream, represent the bottom of a glacial lake. The outlines of this lake cannot now be given. At Ablemans there is a body of loess,[1] the upper surface of which corresponds in elevation with the flat of the Baraboo below.

When the ice lay in the valley of the Baraboo with its edge just west of the city, the stream was effectually dammed. The waters which were held back by the ice dam, reinforced by the drainage from the ice itself, soon developed a lake in the valley of the Baraboo, above the point of obstruction. This body of water likewise extended up the lower course of every tributary, presumably rising until it found the lowest point in the rim of the drainage basin. The location of this point, and therefore its

[1] JOURNAL OF GEOLOGY, Vol. IV, p. 929.

height, and the height of the lake when at its maximum, are not known. But at a point three miles southeast of Ablemans on the surface of a sandstone slope, water-worn gravel occurs, the pebbles of which were derived from the local rock. On the slope below the gravel, the surface is covered with loam which has a suggestion of stratification, while above it, the soil and subsoil appear to be the product of local rock decomposition. This water-worn gravel of local origin on a steep slope facing the valley, probably represents the work of the waves of this lake, perhaps when it stood at its maximum height. This gravel is about 125 feet, according to aneroid measurement, above the Baraboo River.

This lake did not entirely disappear when the ice retreated, for the drift which the ice left, especially the terminal moraine, still obstructed drainage to the east. The moraine, however, was not so high as the former outlet of the lake had been, so that as the ice retreated, the water flowed over the moraine to the east, and drew down the level of the lake. The postglacial valley cut through the moraine is about ninety feet deep.

Besides being obstructed where crossed by the terminal moraine, the valley of the Baraboo was clogged to a lesser extent by deep deposits between the moraine and the Lower Narrows. At one or two places near the city of Baraboo, such obstructions, now removed, appear to have existed. Just above the "Lower Narrows" there is positive evidence that the valley was choked with drift. Here in subsequent time, the river has cut through the drift-filling of the preglacial valley, developing a passage about twenty rods wide and thirty-five deep. If this passage were filled with drift, reproducing the surface left by the ice, the broad valley above it would be flooded, producing a lake. At the outset, this lake must have been considerably lower than the one above the moraine to the west, but drainage from the latter into the former soon lowered the barrier between them, bringing the upper lake to the level of the lower. The lake below Baraboo was much less extensive than the one above, and probably shorter lived. It became extinct by the cutting of its

outlet above the Lower Narrows down to the level of its bottom. The location of this extinct lake is shown on the map, in Fig. 1.

*Other extinct lakes.*—The beds of at least two other extinct ponds or small lakes above the level of the Baraboo are known. These are at *m* and *n*, Fig. 2. They owe their origin to depressions in the drift, but the outflowing waters have cut down their outlets sufficiently to bring them to the condition of marshes. Both were small in area and neither was deep.

From the foregoing it is seen that the small area centering about Devil's Lake presents a number of interesting drift phenomena, some of which are possessed of unusual significance. This is particularly true of the phenomena of the terminal moraine in its passage over the quartzite ridge, and of the phenomena which have led to the determination of the slope of the ice at its extreme edge, along the south side of the quartzite range.

ROLLIN D. SALISBURY,
WALLACE WALTER ATWOOD.

## COMPARISON OF THE CARBONIFEROUS AND PERMIAN FORMATIONS OF NEBRASKA AND KANSAS.[1] II.

### THE WABAUNSEE FORMATION.

*Nebraska City.*— On account of the historic interest attached to the Nebraska City section care was taken to examine the particular exposures studied by Marcou, Meek and Hayden. As a result of this study I have no hesitation in stating that I fully agree with Meek in referring the lower beds of the section (divisions *A* and *B* of Marcou and Meek) to the Upper Coal Measures (Missourian series).[2] On the geological "Map of Nebraska and Dakota" accompanying this report, the Permian is represented as entering the state from Kansas in Jefferson county, west of the Big Blue Valley, then extending to the northeast as a narrowing belt across Lancaster county and down the valley of Saline Creek to the Platte River and thence up the Platte River to Fremont. The town of Lancaster near the present city of Lincoln in Lancaster county, which is the next county west of Otoe, is represented as about halfway across this Permian area. However, in general, on this map the Permian is represented too far to the west, as for example in the Smoky Hill Valley in Kansas, the *base* is represented as near the city of Salina, which in fact is very near the *top;* while the system is mapped as extending some twenty-five miles west of Salina, nearly all of which is now known to belong in the Cretaceous. The same is true in reference to the northern tier of counties where the Permian was represented in Washington and Republic counties in what is known to be Dakota and Ft. Benton. Further-more, it is perfectly clear that the upper part of the section

[1] Continued from p. 16, this JOURNAL.

[2] See the Nebraska City section of Meek in Fin. Rep. U. S. Geol. Sur. Neb., etc., pp. 101, 102.

(divisions *C* and *D*), in reference to the correlation of which Meek was in some doubt,[1] also belongs in the Missourian. Meek plainly saw that there was no basis for referring the upper part of the section to one formation and the lower part to another, for he said: "I can see no reason whatever for drawing any important line of division between the beds included in *C* and those of *B*, or for separating either from the Coal Measures,"[2] though in the closing part of the report he was not sufficiently confident to make an unqualified statement to that effect. However, sections in higher rocks to the north and west of Nebraska City, which will be described farther on in this paper, show conclusively that all the Nebraska City rocks belong in the Missourian.

Meek gave a very complete list of the fossils from divisions *B* and *C* at the former Nebraska City landing (near the present Burlington and Missouri River railroad bridge) which are mostly well-known Upper Coal Measure species.[3] A short distance south of this locality is the quarry of the Nebraska City Vitrified Brick Co. which uses about twenty feet of the upper shales of division *C* of the sections of Marcou and Meek. These shales are mostly of a drab color, somewhat micaceous as well as clayey, and resemble those used for vitrified bricks at the Topeka, Kansas, works. Above the shales of the quarry are ten feet of very sandy shales, changing to soft sandstones, which represent division *D* of the early sections. On the farm of the Hon. J. Sterling Morton, about seventy-five feet above the level of the Missouri River, and again on the river bank one mile below the Nebraska City landing and thirty feet above river level, Meek found a stratum of "black bituminous shale, with a few inches of coal" having a total thickness of one foot, six inches, which was not shown in the Nebraska City section and which he thought must belong above it.[4] The position of this shale has an important bearing upon Meek's correlation, for in an argillaceous limestone immediately above the black shale he found a fauna

[1] Fin. Rep. U. S. Geol. Sur. Neb., etc., p. 130.

[2] *Ibid.*, p. 103.

[3] *Ibid.*, p. 101; also see "Tabular list," pp. 124–127.

[4] *Ibid.*, pp. 103, 104.

which "agrees exactly, so far as they go, with that of division *B* of the section [its lower part] at the landing, with the exception of *Fusulina*."[1] Since the time of Meek's exploration, the construction of the B. & M. R. R. R. along the river bluff below the old steamboat landing has exposed the rocks and shown Meek's supposition regarding the position of the shale to be correct. The following section is shown above the railroad at some distance below the Vitrified Brick quarry:

| | Feet. |
|---|---|
| 8. Massive somewhat calcareous sandstone | $2\frac{1}{2}=37\frac{1}{2}$ |
| 7. Rather arenaceous shales | $15=35$ |
| 6. Limestone with fossils, *Fusulina cylindrica*, etc. (No. 3 of Meek's section on p. 103 of his report) | $1\,1\frac{1}{2}=20$ |
| 5. Black, very bituminous shale with thin layers of coal, one foot, eleven inches (No. 2 of Meek's section) | $1\,1\frac{1}{2}=18\frac{1}{2}$ |
| 4. Mainly argillaceous shales | $9=17$ |
| 3. Arenaceous shales, with thin, irregular sandstone at top | $5=8$ |
| 2. Massive, soft and friable brownish sandstone (about railroad level) 2 and 3 equal division *D* of Meek's section | $3=3$ |
| 1. Argillaceous shales that furnish material for the vitrified bricks (the upper part of division *C* of Meek) | $3=$ |

Numbers 2 and 3 of the above section form division *D* of Meek's section. If the sixty-nine feet measured by Meek, which are below No. 4 of the above section, be added to it there will be a thickness of ninety-eight feet of Palæozoic rocks for the river bluff below Nebraska City. The rocks may be traced along the bluff continuously the greater part of the distance from the Vitrified Brick quarry to the above section, which shows that the stratum of shale and coal is above the sandstone (division *D*) of Meek's section as he supposed.[2]

The dip in the bluff where the above section was measured is nearly 1° to the east of south. From the rocks just above and below the black shale and coal in the quarry and along the bluff to the south the following species were collected. Meek spent nearly a week in the vicinity of Nebraska City, and made

[1] Fin. Rep. U. S. Geol. Sur. Neb., etc., p. 103.

[2] See Meek's discussion of the stratigraphic position of this coal on p. 104 of his report.

a practically complete list of the fossils of that region. No attempt was made to duplicate his work, and only the few species noted below were collected:

*Productus* (*Marginifera*) *splendens* Nor. & Pratt (c). Meek referred this to *P. longispinus* Sow. with which identification Keyes agrees, and probably this is correct.

*Productus costatus* Sowb. (rr).

*Productus punctatus* (Martin) Sowb. (rr).

*Spirifer cameratus* Morton (?) (rr). Imperfectly preserved specimen.

*Chonetes granulifera* Owen (rr).

*Enteletes hemiplicatus* (Hall) H. & C. (rr). Formerly *Syntrilasma hemiplicatus* (Hall) Meek & Worthen.

*Edmondia* sp. (rr). The specimen has rather high beak but is narrower than the figures compared, with quite sharp concentric lines.

*Macrocheilus intercalaris* M. & W. (rr) var. *pulchellus* M. & W. changed by Keyes to *Sphærodoma medialis* (M. & W.) Keyes.

*Fusulina cylindrica* Fischer (c).

*Cythere nebrascensis Geinitz* (?) (c).

Meek found *Spirifer cameratus* in the limestone above the coal associated with plenty of other fossils characteristic of the Upper Coal Measures, so that it is clearly shown by the stratigraphy and palæontology that all of the Palæozoic rocks in the vicinity of Nebraska City belong in the Upper Coal Measures (Missourian) instead of in the Dyas (Permian) as claimed by Marcou. The writer is not confident whether the Nebraska City beds should be referred to the upper part of the Missouri formation or to the Wabaunsee formation of the Missourian series. However, the faunal and lithologic characters of the beds near Nebraska City agree quite closely with those of the lower half of the Wabaunsee formation as shown along the Kansas River above Topeka, and so the writer refers them provisionally to it.

*Dunbar.*—This station on the B. & M. R. R. R. is eleven miles west of Nebraska City and nearly 150 feet higher than the Missouri River at that point. One mile south and one and one-half miles east, or about two miles southeast of Dunbar, on the south side of the B. & M. R. R. R., is the McCartney quarry.

The rocks are well exposed nearly to the level of the railroad, which is about 140 feet higher than the Missouri River at Nebraska City, and above it is a section fifty feet in thickness. The base of this section must be considerably higher than the top of the one at Nebraska City unless there be a reversal in the direction of the dip from that noted there.

SECTION OF THE M'CARTNEY QUARRY.

| | | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|---|
| 11. | Soil | 4 | | = | 56 | |
| 10. | Yellow, very fossiliferous shales. *Spirifer cameratus*, etc. | 1 | | = | 52 | |
| 9. | Slightly reddish shales | 1 | 9 | = | 51 | |
| 8. | Yellowish shales with thin, greenish-gray layers of rather hard limestone which contain abundant specimens of *Myalina perattenuata* and *Pleurophorus occidentalis*. A little black shale | 6 | 3 | = | 49 | 5 |
| 7. | Yellowish, rather soft limestone containing fossils. The quarry stone 1 foot 2 inches thick | 1 | 2 | = | 43 | 2 |
| 6. | Yellowish and drab to greenish argillaceous shale | 6 | | = | 42 | |
| 5. | Red argillaceous shale | 2 | | = | 36 | |
| 4. | Drab to bluish very soft argillaceous shales | 11 | | = | 34 | |
| 3. | Yellowish and rather coarse shales | 7 | | = | 23 | |
| 2. | Shaly yellowish limestones | 3+ | | = | 16 | |
| 1. | Yellowish to drab shales for the upper part; below are reddish shales and the base is covered | 13 | | = | 13 | |

(Railroad level about 140 feet above Missouri River at Nebraska City, or approximately 1050 A. T.)

No. 7 of the above section is a rather soft limestone averaging a little more than one foot in thickness which is used to some extent for foundation and abutment work. This limestone contains some fossils, mostly large Lamellibranchs, as for example:

*Myalina subquadrata* Shum.
*Allorisma subcuneatum* M. & H.
*Aviculopecten occidentalis* (Shum.) M. & W.

The greenish gray slightly arenaceous limestones of No. 8 contain abundant specimens of two specimens of Lamellibranchs. The species collected are:

*Pleurophorus occidentalis* M. & H. (aa). Many of the specimens are external impressions, showing only the concentric lines; one shows radiating lines somewhat indistinctly and there are a number of internal impressions which show very clearly the furrow made by the interior ridge.

*Myalina perattenuata* M. & H. (a).

*Aclis Swalloviana* (Geinitz) M. & H. (?) (rr).

The yellow shales above the quarry stone are quite fossiliferous, No. 10 especially. From these shales of Nos. 8 and 10 the following species were collected, the larger number, however, coming from No. 10:

*Chonetes granulifera* Owen (aa)

*Chonetes lævis* Keyes=(*Chonetes glabra* Geinitz) (c). Some of the specimens are worn and show the radiating fibrous shell structure.

*Hustedia mormonii* (Marcou) H. & C. (c).

*Spirifer* (*Martinia*) *planoconvexus* Shum. (aa).

*Spirifer cameratus* Morton (c).

*Spiriferina kentuckensis* Shum. (rr).

*Athyris* (*Seminula*) *subtilita* (Hall) Newb.

*Productus longispinus* Sowb.=(*P. splendens* N. & P.) (r).

*Productus cora* d'Orbigny (c).

*Productus nebrascensis* Owen (rr).

*Productus semireticulatis* (Martin) de Kon. (c).

*Productus symmetricus* McChesney (rr).

*Enteletes hemiplicatus* (Hall) H. & C. =(*Syntrelasma hemiplicatus* (Hall) Meek) (rr).

*Orthis carbonaria* Swallow (?) (rr). Small specimen that seems to be *Orthis* instead of *Enteletes*.

*Derbya crassa* (M. & H.) H. & C. (rr).

*Lophophyllum proliferum* (McChes.) Meek (c).

*Rhombopora lepidodendroides* Meek (a).

*Fistulipora nodulifera* Meek (aa).

*Zeacrinus* (?) *mucrospinus* McChesney (r).

*Archæocidaris* sp. spines and plates (c).

*Crinoid* stems (r).

*Coral* sp. (rr). A small branching coral something like *Aulopora*.

*Spirifer cameratus* Morton as well as numerous other Upper Coal Measure shells are common in these upper yellow shales. The faunal and lithologic characters of the section agree closely with those of the Wabaunsee formation, to which it is referred. Inasmuch as the rocks of this section are still higher than

any of those exposed at Nebraska City we have conclusive proof that no part of that section belongs in the Permian. Time did not permit me to continue this section as far west as the Cretaceous; but in the soil and on the surface to the south and west of Dunbar are numerous loose specimens of the brownish-red Dakota sandstone.

## CASS COUNTY.

### THE WABAUNSEE FORMATION.

*Nehawka.*—Directly north of Otoe county is Cass county, whose eastern border is formed by the Missouri River, and the greater part of the northern by the Platte River. In the southern part of the county is Weeping Water Creek, along which are rather low bluffs in which the rocks are quite well shown from Nehawka to the vicinity of Wabash. Meek described a section on this creek called Cedar Bluff, about six miles above its mouth. The section had a thickness of 88+ feet, all of which he correctly referred to the Upper Coal Measures.[1]

The village of Nehawka is sixteen miles by rail northwest of Nebraska City and about one-half mile east of it is the Van Court and Lemist quarry which has been worked for six years. The floor of the quarry is between 90 and 95 feet, according to surveyor's level, above the Nehawka Railroad station, which makes its elevation 170 feet or more above the Missouri River level at Nebraska City, or approximately 1085 A. T.

SECTION OF THE NEHAWKA QUARRY.

| | | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|---|
| 10. | Loess | 10 | | = | 42 | 3 |
| 9. | Light gray to slightly bluish limestones that weather yellowish, all of which are worked for quarry stone. They are moderately fossiliferous, especially the shaly parts, *Athyris subtilita* being the most common | 18 | | = | 32 | 3 |
| 8. | Shaly limestones | 2 | | = | 14 | 3 |
| 7. | Yellow shales that are used for bricks | 1 | | = | 12 | 3 |
| 6. | Limestone used for bridges, the strongest in the quarry | | 10 | = | 11 | 3 |
| 5. | Yellowish shale used for vitrified bricks | 1 | | = | 10 | 5 |

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, pp. 97–99.

SECTION OF THE NEHAWKA QUARRY—*continued.*

| | | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|---|
| 4. | Black shale that is quite bituminous - - - | 1 | 4 | = | 9 | 5 |
| 3. | Limestone, best building stone in quarry - - | | 7 | = | 8 | 1 |
| 2. | Limestones at base of quarry. Floor 90 to 95 feet above railroad level - - - - - - - - - | 1 | 6 | = | 7 | 6 |
| 1. | Yellow to buff arenaceous shales in railroad cut under quarry - - - - - - - - - - | 6 | | = | 6 | |

The dip is small and toward the east. About twenty-two feet of the limestones are worked, the stone being crushed and used for railways and highways. Some of it is also burned for quicklime. The shale was formerly sent to Louisville, where it was burned for vitrified brick. There are some fossils in the upper limestones, especially in the shaly partings, yet, with the exception of *Athyris subtilita*, no species can be said to be abundant. These upper limestones, No. 9 of the section, furnished the following species:

*Athyris* (*Seminula*) *subtilita* (Hall) Newb. (aa).
*Spirifer cameratus* Morton (c).
*Derbya crassa* (M. & H.) H. & C. (r).
*Productus* (*Marginifera*) *longispinus* Sowb. (r).
*Productus costatus* Sowb. (?) (rr).
*Productus semireticulatus* (Martin) de Koninck. Fragment of specimen (rr).
*Hypothyris* (*Pugnax*) *uta* (Marcou) H. & C. (r).
*Hustedia mormonii* (Marcou) H. & C. (rr).
*Meekella striato-costata* (Cox) White & St. John (r).
*Spirifer* (*Martinia*) *lineatus* Martin (rr).
*Lophophyllum proliferum* (McChesney) Meek (c).
*Zeacrinus* (?) *mucrospinus* McChesney (rr).
*Fusulina cylindrica* Fischer (rr).
(?) *Chætetes* cf. *carbonarius* Worthen (r).
*Coral* or *sponge* sp. Large one, genus not yet determined (rr).
*Crinoids*. Fragments of stems (rr).
*Naticopsis nana* M. & W. Small and imperfectly preserved (rr).

On account of the faunal and lithologic character of the rock the above exposures are referred to the Wabaunsee formation. The quarryman reported an outcrop of coal in the bed of the creek near Nehawka and estimated that the bottom of

the quarry was about 200 feet higher than the coal at Nebraska City.

*Weeping Water.*—This village is nine miles up the Weeping Water Creek from Nehawka, and for about seven miles the valley is bounded by low rounded bluffs. Beyond this the bluffs are steeper, their crest being formed by heavy limestones. This type of valley is conspicuously shown in the vicinity of the village, the sides of the bluffs being partly covered by large blocks of the massive limestone that have fallen from their original position. They continue steep, being marked by a prominent limestone stratum, for rather more than two miles above Weeping Water, when they again become lower with rounded slopes.

The first outcrop studied above the Nehawka quarry is seven miles up the Weeping Water valley, at a locality known as the "Swede quarry" on the north side of the Missouri Pacific Railway. It is only a few rods from the railroad, between twenty-five and thirty feet higher, with an approximate elevation of 1080 feet A. T.

SECTION OF THE SWEDE QUARRY.

| | | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|---|
| 6. | Massive yellowish to brownish gray limestone, that weathers whitish | 1 | | = | 18 | 9 |
| 5. | Yellowish shale | | 10 | = | 17 | 9 |
| 4. | Somewhat reddish limestone | 1 | 4 | = | 16 | 11 |
| 3. | Rather irregular, massive limestone, of yellowish to pinkish color, containing large numbers of *Fusulina cylindrica* Fischer, 2 to 2¼ feet thick. This limestone resembles somewhat the chocolate limestone of Swallow as it occurs along the Kansas valley near Maple Hill, Kansas | 2 | 3 | = | 15 | 7 |
| 2. | Yellowish soft shales, immense numbers of *Fusulina*. *Spirifer cameratus* is also common; 2¼–3 feet thick | 3 | | = | 13 | 4 |
| 1. | Massive limestone of rather light gray to buff color. The quarry rock. Flint in upper part of stratum and all of it quite free from fossils | 10 | 4 | = | 10 | 4 |

The following species were collected in the above quarry, the greater number from the yellow shales of No. 2:

*Athyris* (*Seminula*) *subtilita* (Hall) Newb. (c).
*Spirifer cameratus* Morton (a).
*Enteletes hemiplicatus* (Hall) H. & C. (rr).
*Productus semireticulatus* (Martin) de Koninck (?). Only fragments (rr).
*Chonetes granulifera* Owen (rr).
*Spiriferina kentuckensis* Shum. (r).
*Hustedia mormonii* (Marcon) H. & C. (rr).
*Rhombopora lepidodendroides* Meek (c).
*Lophophyllum proliferum* (McChes.) Meek (rr).
*Zeacrinus* (?) *mucrospinus* McChesney (r).
*Fusulina cylindrica* Fischer. Very abundant in some shaly limestones (aa).
*Campophyllum torquium* (Owen) Meek (rr).
*Phillipsia scitula* M. & W. (rr).
*Archæocidaris* sp. Plate and spines (r).
*Productus nebrascensis* Owen (rr).
*Fistulipora nodulifera* Meek (c).
*Crinoids.* Segments of large stems (r).

The above fauna is that of the Wabaunsee formation and the reddish to pinkish limestones are similar in appearance to limestones near the middle of the formation in Kansas.

The heavy limestone near the crest of the bluff on the northern side of the creek is very prominent both above and below Weeping Water for some distance, as well as in the village itself. Perhaps the best section of the limestone and underlying rocks is afforded by the Reed quarry, one-half mile east of the village. It is north of the railroad, the base of the *Fusulina* shaly limestone being about eighty feet above railroad level or approximately 1160 feet A. T.

SECTION OF THE REED QUARRY.

| | | Ft. | | Ft. |
|---|---|---|---|---|
| 9. | Loess, 10 to 12 feet - - - - - - - | 12 | = | 63½ |
| 8. | Massive light gray limestone weathering to a whitish color. This is the main quarry stone. It is crushed for railroad ballast and burned for lime which slacks and sets very quickly. In some places it reaches a thickness of 12 feet. Some flint and iron pyrites in upper part - | 9 | = | 51½ |
| 7. | Shaly buff to yellowish fossiliferous limestone containing abundant *Fusulinas* in the upper 4 feet and in lower part *Spirifer cameratus*. Used for riprap. Base about 80 feet above railroad level - - - - - | 6¾ | = | 42½ |

SECTION OF THE REED QUARRY—*continued.*

| | | Ft. | | Ft. |
|---|---|---|---|---|
| 6. | Yellowish shale with plenty of *Spirifer cameratus* | 1 ⅓ | = | 35 ⅚ |
| 5. | Buff to yellowish limestone (not valuable) - - | 1 | = | 34 ½ |
| 4. | Black, bituminous shale - - - - - - | 2 | = | 33 ½ |
| 3. | Limestone quarried for building stone - - - | 1 ½ | = | 31 ½ |
| 2. | Greenish argillaceous shales - - - - | 30± | = | 30 |
| 1. | Red shale, thickness undetermined. This stratum shows in the village and also in a railroad cut above it. | | | |

The shaly yellowish limestone, No. 7, of this quarry contains quite a number of fossils, especially in its lower part. The following species were collected:

*Athyris* (*Seminula*) *subtilita* (Hall) Newb. (a).
*Spirifer cameratus* Morton (c).
*Enteletes hemiplicatus* (Hall) H. & C. (c).
*Hypothyris* (*Pugnax*) *uta* (Marcou) H. & C. (r).
*Chonetes granulifera* Owen (rr).
*Productus longispinus* Sowb. (rr).
*Spirifer lineatus* Martin (rr).
*Spiriferina kentuckensis* Shum. (rr).
*Lophophyllum proliferum* (McChes.) Meek (a).
*Fusulina cylindrica* Fischer. Abundant in some layers of the yellowish shales (aa).
*Coral* or *sponge* sp. Large, undetermined species (c.)
*Chaetetes* cf. *carbonarius* Worthen (r).
*Crinoid* stems (rr).

The main quarry stone, No. 8, which is a very light gray compact limestone, contains but few fossils, except *Athyris subtilata* (Hall) Newb. Sections of this species, the interior of the shells filled with calcite crystals, are not uncommon in the limestone. In places there are crystals of iron pyrites, some of them large, that on weathering stain the stone as may be seen in some of the buildings in Weeping Water. The following species were collected in the massive limestone of the Reed quarry:

*Athyris* (*Seminula*) *subtilita* (Hall) Newb. (c). In the somewhat rough partings and apparently in the massive limestone.
*Productus longispinus* Sowb. (rr).

*Meekella striato-costata* (Cox) White & St. John (rr).
*Lophophyllum proliferum* (McChes.) Meek (rr).
*Pleurotomaria* sp. Small and imperfectly preserved (rr).
*Crinoid* stems. Some flint with iron in the limestones (rr).

This massive limestone, which from its great prominence in the vicinity of Weeping Water might be termed the Weeping Water limestone,[1] may be followed in the bluffs for three miles above Weeping Water. At the turn in the highway on the north side of the creek about halfway between Weeping Water and Wabash is the last exposure of the Weeping Water stone that was seen. The limestone at this locality is a light gray massive one that weathers to a whitish color, and closely resembles the heavy ledge in the vicinity of Weeping Water. Below are yellowish, shaly limestones with abundant specimens of *Fusulina cylindrica* Fischer, the same as in the Reed quarry. Estimated from one barometric reading, the elevation of the base of the above limestone is 1180 feet A. T., and as the base, in the Reed quarry, three and one-half miles to the east, is 1166 feet there is a dip of four feet per mile to the east. At this place the following species were collected from the Weeping Water limestone:

*Athyris* (*Seminula*) *subtilita* (*Hall*) Newb. (c).
*Productus longispinus* Sowb. (c).
*Hypothyris* (*Pugnax*) *uta* (*Marcou*) H. & C. (rr).
*Productus pertenuis* Meek (rr).
*Meekella striato costata* (Cox) White & St. John (rr). Very imperfect specimen.

Dr. Hayden briefly described the Weeping Water stone as a "limestone, hard, whitish, and yellowish white; cropping out at the summits of the hills, and lying on the slopes in large masses eight to ten feet thick,"[2] accompanied by a rather general section of the bluff. He also described the following shaft beginning in the Weeping Water valley near creek level:

[1] This is not intended as a formation name, but is merely used for convenience in speaking of this limestone stratum.

[2] Loc. cit., p. 14.

| | Feet. | | Feet. |
|---|---|---|---|
| 9. Sandstones that form the creek bed | 10 | = | 30 |
| 8. Slate and clay | 3 | = | 20 |
| 7. Coal, nine inches | ¾ | = | 17 |
| 6. Whitish, fire clay | 3 | = | 16¼ |
| 5. Crystalline quartz, three inches | ¼ | = | 13¼ |
| 4. Bluish clay | 4 | = | 13 |
| 3. Whitish, fire clay | 6 | = | 9 |
| 2. Red clay | 3 | = | 3 |
| 1. Soft white limestone | | | |

The above section is important from the fact that it shows a stratum of coal, nine inches thick, about 100 feet below the base of the Weeping Water limestone.

The very light gray to whitish color on the weathered surface of the Weeping Water limestone suggests at first the Permian limestones of Kansas, as, for example, the Strong flint at the base of the Chase formation; but the fauna, especially of the shaly limestones just below, indicates that they belong to the Wabaunsee.

One mile below Wabash, on the south bank of Weeping Water Creek, is the small Flowers' quarry.

SECTION OF FLOWERS' QUARRY.

| | Feet. |
|---|---|
| 4. Yellowish, coarse shales, containing plenty of fossils. Thickness not determined. | |
| 3. Drab, compact limestone in three layers, containing a good many fossils, especially *Productus pertenuis* in the shaly parting, | 3½ |
| 2. Thin layer of black bituminous shale, | 5 |
| 1. Bluish coarse shales to creek level, | |

The quarry stone, No. 3, has been worked to a limited extent for foundation stone. One reading of the barometer compared with the R. R. elevation at Weeping Water makes this limestone 1150 feet A. T. This indicates that it is below the Weeping Water stone, which is exposed two miles farther east on the north side of the creek. The following fossils were found in this limestone:

*Spirifer cameratus* Morton (r).
*Chonetes granulifera* Owen (r).

*Productus pertenuis* Meek (c).
*Productus nebrascensis* Owen (r).
*Spiriferina kentuckensis* Shum. (c).
*Productus longispinus* Sowb. (c).
*Athyris* (*Seminula*) *subtilita* (Hall) Newb. (c).
*Hustedia mormonii* (Marcou) H. & C. (rr).
*Phillipsia scitula* M. and W. (rr).
*Rhombopora lepidodendroides* Meek (rr).
*Spirifer* (*Martinia*) *planoconvexus* Shum. (rr).

The yellowish shales, No. 4, above the quarry stone have the following fauna:

*Athyris* (*Seminula*) *subtilita* (Hall) Newb. (aa).
*Chonetes granulifera* Owen (a).
*Spirifer cameratus* Morton (r).
*Productus nebrascensis* Owen (c).
*Productus longispinus* Sowb. (r).
*Productus cora* d'Orbigny (c). Perhaps one of the specimens is *P. costatus* Sowb. as it has a faint sinus.
*Derbya crassa* (M. & H.) H. & C. (c).
*Productus pertenuis* Meek (rr).
*Productus semireticulatus* (Mart.) de Koninck (rr).
*Myalina swallowi* McChesney (r).
*Myalina subquadrata* Shum. (rr).
*Myalina perattenuata* M. & H. (rr).
*Myalina kansasensis* Shum. (?) (rr). Small specimen. Characters not clearly shown.
*Fusulina cylindrica* Fischer (aa). In some layers of the yellowish shales.
*Aviculopecten occidentalis* (Shum.) M. & W. (rr).
*Rhombopora lepidodendroides* Meek (r).
*Lophophyllum proliferum* (McChes.) Meek (rr).
*Septopora biserialis* (Swallow) Waagen (r).
*Zeacrinus mucrospinus* McChesney (rr). Calyx and spine.
*Crinoids* (r). Segments and parts of quite large stems.

These were the last rocks found in place along Weeping Water Creek which are shown by their fauna to belong in the Wabaunsee formation.

One mile to the west of Wabash and rather more than 100 feet higher than the Flowers' quarry, the general level of the upland is reached. There are very few exposures on these higher slopes along the upper part of the Weeping Water val-

ley, the country being gently rolling and the rocks deeply covered by loess and soil. According to a residing farmer on this upland, a well fifty-six feet deep did not strike hard rock but was dug "in dirt" for its entire depth.

*Louisville.*—Ten miles due north of Weeping Water is Louisville on the Platte River. The Missouri Pacific Railroad station is 1042 feet A. T. or thirty-eight feet lower than that at Weeping Water. The Platte River is shallow, with numerous sand bars, and at this locality is nearly one-half mile wide, lined on both sides with moderately steep bluffs. In these bluffs, both above and below the town, are a number of quarries which have been or are extensively worked and so afford an excellent idea of the geology of this region. On the south side of the river are several quarries and a section of one, the Parmlee, about three-fourths of a mile west of the town and south of the B. & M. R. Railroad was measured. According to the barometer, the floor of this quarry is some sixty feet above the Platte River which makes it approximately 1070 feet A. T.

THE PARMLEE QUARRY SECTION:

| | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|
| 8. Loess | 10± | | = | 32 | 8 |
| 7. Rather rough light gray to yellowish, very fossiliferous limestone | 3 | 6 | = | 22 | 8 |
| 6. Yellow, very fossiliferous clay shales. *Spirifer cameratus* | 1 | 2 | = | 19 | 2 |
| 5. Light gray limestone, not in western part of quarry | 2 | | = | 18 | |
| 4. Green argillaceous shales | | 6 | = | 16 | |
| 3. Red or maroon argillaceous shales | 6 | | = | 15 | 6 |
| 2. Rather shaly, slightly greenish limestone and shale | 2 | 6 | = | 9 | 6 |
| 1. Quite massive light gray limestone, somewhat fossiliferous. Quarry stone. Bottom of quarry approximately 1070 feet A. T. | 7 | | = | 7 | |

The massive limestone, No. 1, of the Parmlee quarry, contains some fossils, the larger number of specimens occurring in the somewhat shaly partings. The following species were obtained:

*Athyris* (*Seminula*) *subtilita* (Hall) Newb. (a).
*Productus longispinus* Sowb. (c).

*Productus nebrascensis* Owen (rr).
*Spiriferina kentuckensis* Shum. (rr).
*Fusulina cylindrica* Fischer (a). Abundant in certain layers.
*Archæocidaris* sp. (rr). Spine.
*Bellerophon carbonarius* Cox (?) (r). Imperfectly preserved specimens of the size and shape of this species; one specimen shows concentric striæ that are not mentioned in the description.
*Crinoids.* (c). Segments of stems.

The yellow shales, No. 6, contain a larger number of species and more numerous specimens. The list is as follows:

*Athyris* (*Seminula*) *subtilita* (Hall) Newb. (c).
*Chonetes verneuiliana* N. & P. (aa).
*Chonetes granulifera* Owen (c).
*Productus longispinus* Sowb. (rr).
*Productus nebrascensis* Owen (r).
*Spirifer* (*Martinia*) *planoconvexus* Shum. (r).
*Spirifer cameratus* Morton (r).
*Derbya crassa* (M. & H.) H. & C. (rr).
*Spiriferina kentuckensis* Shum. (rr).
*Lophophyllum proliferum* (McChes.) Meek (rr).
*Rhombopora lepidodendroides* Meek (c).
*Septopora biserialis* (Swallow) Waagen (c).
*Chætetes* cf. *carbonarius* Worthen (rr).
*Scaphiscrinus* (?) *hemisphæricus* (Shum.) Meek (r).
*Crinoid*, loose plates and also segments of stems.

Along the bluff on the northern side of the Platte River, opposite the Parmlee quarry, in Sarpy county, are several quarries that afford excellent exposures. These qnarries contain reddish shales above the light gray limestone and when seen from the southern side of the river in bright sunshine form a very striking feature of the landscape. The Rock Island railroad follows the valley just below the bluff and the quarries have been worked extensively for both building stone and rock ballast. The Green quarry, near the eastern end of the quarries, gives a good section from a little above the railroad level nearly to the crest of the bluff. It may be considered as divided into a lower and an upper section, separated by thirty-nine feet of covered slope. A few rods to the east is another small quarry

in rocks belonging to the same strata as those of the lower Green quarry.

SECTION OF THE GREEN QUARRY.

| | | Ft. | | Ft. |
|---|---|---|---|---|
| 16. | Soil containing bowlders of Dakota sandstone 2 to 3 feet thick | 3 | = | 112½ |
| 15. | Light gray sandstone | 5+ | = | 109½ |
| 14. | Shale with abundant ferruginous concretions (probably the base of the Dakota sandstone) | ½ | = | 104½ |
| 13. | Brownish yellow shales containing large flint pebbles mixed with others | 1 | = | 104 |
| 12. | Yellowish brown shale | 1 | = | 103 |
| 11. | Red shale more compact than that in the Parmlee quarry on the south side of the Platte River | 4 | = | 102 |
| 10. | Yellowish shaly limestones | 4 | = | 98 |
| 9. | Gray limestone, in some places very light gray and in others yellowish. Fossiliferous (same as quarry stone No. 7 of Parmlee quarry on south side of the Platte) | 7 | = | 94 |
| 8. | Covered slope | 39 | = | 87 |
| 7. | Brownish yellow limestone that weathers to an ochre color. Contains large numbers of fragments of shells | 2 | = | 48 |
| 6. | Very yellow soft shales | 3+ | = | 46 |
| 5. | Grayish, somewhat shaly limestone | 1+ | = | 43 |
| 4. | Massive grayish limestone with brownish specks and blotches. Some *Fusulinas* and other fossils. Lower part brownish-red in places | 6½ | = | 42 |
| 3. | Yellowish shaly limestone and shales | 1½ | = | 35½ |
| 2. | Light gray to drab and bluish limestone; the upper part is more shaly. Contains fossils, especially *Athyris subtilita* | 12 | = | 34 |
| 1. | Covered slope, level of Platte River, near 1010 feet A. T. | 22 | = | 22 |

The limestones, Nos. 2 and 9, of the above section are quite fossiliferous, especially the more shaly layers. In No. 2 the following species were collected:

*Athyris* (*Seminula*) *subtilita* (Hall) Newb. (a).
*Spirifer cameratus* Morton (r).
*Productus costatus* Sowb. (r).
*Productus longispinus* Sowb. (rr).
*Productus nebrascensis* Owen (rr).

*Productus semireticulatis* (Mart.) de Kon. (?). Imperfectly preserved (rr).
*Spiriferina kentuckensis* Shum. (rr).
*Fistulipora nodulifera* Meek (rr).
*Fusulina cylindrica* Fischer (r).
*Zeacrinus* (?) *mucrospinus* McChesney (rr).
*Archæocidaris* sp. Spines (rr).
*Crinoids.* Large column (rr).

FIG. 2. View in western part of Green quarry north of Platte River at Louisville, showing line of unconformability between Dakota sandstone and Carboniferous limestone. The hammer marks the limestone, No. 3 of section, on which the Dakota sandstone rests, and only three feet to the west, marked by the pick, the limestone is wanting and the Dakota rests on shales of No. 2.

The shaly layers of No. 9 did not furnish as large a number of species as No. 2, though the first two species of the following list were more abundant in the upper than in the lower limestone. The fauna is:

*Athyris* (*Seminula*) *subtilita* (Hall) Newb. (a).
*Productus longispinus* Sowb. (c).

*Productus costatus* Sowb. (rr).
*Productus semireticulatus* (Mart.) de Kon. (rr).
*Spiriferina kentuckensis* Shum. (rr).
*Derbya crassa* (M. & H.) H. & C. (rr).
*Archæocidaris* sp. Plate and spines (r).

A little farther west in the upper Green quarry is an excellent exposure that differs somewhat from the one just described The section is as follows, commencing at the top of the red shales, No. 11, of the eastern part of the Green quarry:

| | Ft. | In. | | Ft. | In. |
|---|---|---|---|---|---|
| 6. Soil | 1 | | = | 10 | 5 |
| 5. Light gray to whitish arenaceous deposit (very friable sandstone probably belonging to the Dakota) | 5 | 6 | = | 9 | 5 |
| 4. Dark to yellowish brown sandstone; base of Dakota sandstone. Prominent line of unconformity | | 8 | = | 3 | 11 |
| 3. Massive light gray limestone | 1 | 3 | = | 3 | 3 |
| 2. Yellowish and greenish shales, | 2 | | = | 2 | |
| 1. Top of the red shales (No. 11 of the eastern part of the quarry). | | | | | |

This part of the quarry shows very clearly the line of unconformity due to erosion between the Carboniferous (Wabaunsee) and Cretaceous (Dakota) systems. In places the dark brown Dakota sandstone rests on the gray limestone, No. 3; while not more than three feet away the gray limestone is entirely absent, having been worn away before the deposition of the Cretaceous, and the Dakota sandstone rests on the yellowish shales, No. 2, of the section. When this section was studied the upper rocks for several rods had been recently removed, so that the several strata and the line of unconformity were clearly shown. The line of unconformity is shown in the accompanying picture, where the small hammer shows the Dakota resting on the limestone of No. 3, and the pick shows it resting on the shales of No. 2. Many of the large blocks of rock from the wall of the quarry showed clearly the line of contact, the non-calcareous brown Dakota sandstone closely united to the yellowish calcareous shales in which were fragments of shells. A few rods west of the quarry just described, and across a small run, is another large quarry called the Cooley, which gave the following section:

| | | Ft. | In. | | Ft. | In |
|---|---|---|---|---|---|---|
| 11. | Soil, | | | | | |
| 10. | Light gray compact limestone | 1 | | = | 30 | |
| 9. | Red shale in upper part, green shale in lower part | 2 | 6 | = | 29 | |
| 8. | Very compact light gray limestone, with some flint | 1 | 6 | = | 26 | 6 |
| 7. | Coarse, grayish shale | 1 | | = | 25 | |
| 6. | Greenish argillaceous shale | 3 | 6 | = | 24 | |
| 5. | Massive grayish compact limestone, with fossils | 2 | 4 | = | 20 | 6 |
| 4. | Yellowish shales that are greenish at the base | 2 | | = | 18 | 2 |
| 3. | Red, argillaceous shales | 6 | 6 | = | 16 | 2 |
| 2. | Shaly grayish and yellowish limestones changing to shales | 2 | 6 | = | 9 | 8 |
| 1. | Massive, grayish limestone (bottom of the quarry,) | 7 | 2 | = | 7 | 2 |

FIG. 3. View in eastern part of Cooley quarry, north of Platte River at Louisville Nos. 1–5 of the section are shown.

From the somewhat shaly layers of No. 1 of this quarry the following fossils were collected:

*Athyris* (*Seminula*) *subtilita* (Hall) Newb. (r).
*Productus costatus* Sowb. (rr).
*Productus cora* d'Orbigny (r).

*Myalina* cf. *recurvirostris* M. & W. (rr). Beak is gone and the specific identification is not positive on that account.

The rocks at the eastern end of this quarry are well shown in Fig. 3 of the pictures, the heavy stratum near the bottom of the picture forming the top of No. 1, which is succeeded by Nos. 2–5 of the section.

The quarry limestone, No. 1, of the above quarry is the same stratum as No. 9 (the quarry limestone) in the eastern part of the Green quarry. The yellowish shales, Nos. 12 and 13, of the eastern part of the Green quarry, No. 2 of the western part, and No. 4 of the Cooley quarry are the same stratum. In the Green quarry the Dakota sandstone rests on either these yellowish shales or the overlying limestone (No. 3) of the western part of the Green quarry; but in the Cooley quarry there is no Dakota sandstone, though Carboniferous rocks with a thickness of eleven feet ten inches are shown above the yellowish shales. In the Green quarry these rocks, with the exception of the limestone, No. 3, in its western part, were eroded before the deposition of the Dakota sandstone. The above data obtained on comparing the Cooley and Green quarries show that the Dakota sandstone was deposited in a very irregular Carboniferous floor.

The massive quarry limestone in the quarries north of the Platte River, No. 9 of the Green and No. 1 of the Cooley, is the same stratum as that quarried in the Parmlee quarry, No. 1, on the south side of the river. The difference in elevation of the base of this limestone on opposite banks of the river, 1097 feet A. T. on the north side, and 1070 on the south side, may be due partly to an error in the barometric record, though there is probably some dip in that direction. In the Parmlee quarry fifteen feet, eight inches of Carboniferous rocks are exposed above the top of the quarry limestone, No. 1 of the section, without showing the Dakota; in the Cooley twenty-three feet are exposed, and in the eastern part of the Green quarry there are ten feet capped by the Dakota. This comparison between the north and south sides also shows the irregularity of surface upon which the

Dakota sandstone was deposited. Dr. Hayden saw the contact of the Carboniferous and Cretaceous rocks; but apparently at localities where there is not such a clear line of unconformity, for he said: "We find at one or two localities the Cretaceous and Carboniferous beds in apposition; and though the eye can observe no apparent want of conformity in these beds, yet we can readily imagine the tremendous effects of the erosion prior to the deposition of the sandstone, from the fact that hundreds of feet of clays and limestones must have been swept away."[1]

In the lower limestone, No. 2, of the Green quarry are specimens of *Spirifer cameratus* associated with other species of the Wabaunsee formation; while in the Parmlee quarry a similar fauna with *Spirifer cameratus* is found in the yellowish shales, No. 6, above the quarry limestone. On account of this fauna and their stratigraphic position, all of the Carboniferous rocks in the vicinity of Louisville are referred to the Wabaunsee formation. On the Platte River, the Permian is not represented and the Dakota sandstone rests unconformably on the limestones and shales of the Wabaunsee formation. This is consequently a very important section as it shows that the 800 feet of Permian rocks exposed along the Kansas and Smoky Hill rivers in Kansas have disappeared and the Dakota sandstone of the Cretaceous system rests on the Wabaunsee formation of the Missourian series or Upper Carboniferous. This conclusion agrees with that of Dr. Hayden who on his "Geological Map of Nebraska" published in 1858 represented the Lower Cretaceous (now known as the

[1] Fin. Rep. U. S. Geol. Sur. Nebraska, p. 9. Also on p. 8 is the statement that "near the old Otoe village, eight miles above the mouth of the Platte [is] a good exposure of the sandstone resting conformably on the Carboniferous limestone." As early as 1858 Meek and Hayden reported the Cretaceous sandstone on the Platte River as resting "directly upon Carboniferous rocks" near the mouth of the Elk Horn River which is some twenty miles above Louisville (Proc. Acad. Nat. Sci. Phil., Vol. X, p. 259). However, it appears that in these early explorations of Meek and Hayden they did not recognize the unconformity between the Carboniferous and Cretaceous for in January 1859, they published the following statement: "In conclusion we would state that there is no unconformability so far as our knowledge extends, amongst all the rocks of Nebraska and northeastern Kansas, from the Coal Measures to the top of the most recent Cretaceous" (Am. Jour. Sci., 2d ser., Vol. XXVII, p. 35).

Dakota sandstone) on the Platte River as resting on the Carboniferous.[1] On this map the Permian was represented as thinning out and disappearing at a locality apparently several miles north of Dunbar and northwest of Nebraska City; while in the report of 1872 Dr. Hayden clearly expressed this conclusion in describing the geology of Douglas and Sarpy counties. Dr. Hayden said: "If the Permo-Carboniferous and the Permian were ever deposited over this area, they were swept away by erosion prior to the deposition of the Cretaceous rocks. If we follow the valley of the Platte westward on the northern side, we shall see the junction of the two great periods, Carboniferous and Cretaceous, and we shall find that the beds of the Dakota group, or what we suppose to be the Lower Cretaceous beds of the west, rest directly down on the limestones of the Upper Coal Measures."[2] There seems to have been some error in coloring the geological map accompanying this report, for on it the Permian is represented as reaching the Platte valley at Saline, now called Ashland, thirteen miles above Louisville, and then extending up the Platte some twenty miles to Fremont. As a matter of fact along the river to the east of Ashland are fine exposures of the Dakota sandstone.

Meek described a section of rocks on the north side of the Platte River between three and four miles above its mouth (about ten miles northeast of Louisville) which by their fossils are shown to belong to the Upper Carboniferous, probably the Wabaunsee formation.[3]

On the ridge to the south of Louisville are exposures of the lower part of the Dakota formation. One of these is in the "Fire Clay" quarry of Captain Hoover, one and one-half miles south of the village (Sec. 27, Tp. 12, Range 11) where an opening of about fifty feet has been made in working the middle part of the section for fire clay. The exposure begins on the bank of a small run with an approximate altitude of 1100 feet A. T.

[1] Proc. Acad. Nat. Sci., Phil., Vol. X.

[2] Fin. Rep. Geol. Sur. Neb., p. 7.

[3] *Ibid.*, pp. 90–93.

SECTION OF CAPTAIN HOOVER "FIRE CLAY" QUARRY.

| | Feet. |
|---|---|
| 7. Soil containing bowlders of hard, dark brown Dakota sandstone | 1 = 53 |
| 6. Light brown to rusty brown color friable sandstone with streaks of iron brown. In the upper part, some of the hard, dark brown sandstone (line of irregular bedding) - | 14 = 52 |
| 5. Brownish friable sandstone, six inches to two and one-half feet thick, the difference in thickness being due to the irregular line limiting the top of this stratum - - - | 2½ = 38 |
| 4. Very hard dark brown sandstone - - - - - - | ½ ± = 35½ |
| 3. Brown conglomerate with plenty of small pebbles of quartz, flint, etc. - - - - - - - - - - - | ½ = 35 |
| 2. Somewhat arenaceous fire clay of light gray to almost white color with pinkish layers. Some layers of friable light gray to whitish sandstone; also of brownish yellow color. About fifteen feet of this part of the section used for fire clay - - - - - - - - - - - - | 30 = 34½ |
| 1. Yellowish, very soft and friable sandstone with dark brown streaks (bottom of exposure below the quarry) - | 14½ = 14½ |

In the other quarry of Captain Hoover (Sec. 23, Tp. 12, Range 11) the Dakota sandstone has been quarried and used to a considerable extent in the village buildings. The stone out of which Captain Hoover's house was built some thirty years ago has hardened somewhat on exposure, and in many of the blocks the marks of the tools used in dressing may still be seen. According to the Captain there is about twenty feet of this dark brown sandstone that may be quarried. It is interesting to note the difference in consolidation of the same layers of the Dakota sandstone when separated by only a short distance. The Hoover quarries are only about one-half mile apart and still the comparatively massive brown quarry sandstone just described is the same stratum as the friable light brown sandstone, No. 6, of the "Fire Clay" quarry.

Below the sandstone on section 23 is from fifteen to twenty feet of the light gray to pinkish fire clay. The clay from both of these quarries is made into pottery and is also used in Union Pacific foundry shops and for crucibles and the lining of retorts in smelters. A considerable amount of it is shipped to Omaha for use in the gold and silver smelters. Samples were shown me

of similar colored fire clay from a pit near the edge of the village. The conglomerate stratum, No. 3, of the "Fire Clay" quarry is also present at the base of the sandstone in the Hoover sandstone quarry. Near Captain Hoover's house, below the sandstone and fire clay, the Wabaunsee limestone is shown; but the contact between the Wabaunsee and Dakota formations is covered by soil.

CHARLES S. PROSSER.

UNION COLLEGE,
Schenectady, N. Y., October 1896.

## THE GEOLOGY OF SAN FRANCISCO PENINSULA.

DR. HAROLD W. FAIRBANKS accuses me in a paper published in the last number of the JOURNAL OF GEOLOGY of ignoring him. I have written a "Sketch of the Geology of the San Francisco Peninsula" and in doing so I have "given my attention almost exclusively to a narrow field of complex geology and have failed to make use of the results of the work of *others*." "Others" is a modest euphemism for Dr. Harold W. Fairbanks, as appears from a succeeding statement to the effect, that, in my paper "there is a failure to give recognition to some contemporaneous and earlier work in the same general field," which statement is annotated by a reference to a paper of his published as a bulletin of the Geological Society bearing the date December 1894. If the charge applies to this particular paper it is baseless. My "Sketch" was forwarded for publication in June 1894, six months or more before the appearance of the bulletin which he insists should have been recognized. If it applies to earlier papers I must plead charitable motives in gently passing them over without comment. Justice, too, joined with mercy in barring me from quoting from his earlier papers statements which he has since repudiated, as for example, regarding the age of the granite of the Coast Ranges. It would have been scarcely fair to quote from himself views in which it now "seems to him there is no validity whatever." Dr. Fairbanks is fortunately not to be measured by his earlier papers, and the marked improvement in his later work, due in some measure to good University laboratory discipline, commands the respect and recognition which it deserves.

Evidently grieved at the supposed discourtesy with which he charges me, Dr. Fairbanks proceeds to subject my "Sketch" to a "friendly criticism." The friendliness is gratefully appreciated but the object of it is troubled with an uncanny curiosity as to

what manner of criticism he should deal out to his *enemy*, should that unfortunate be so foolish as to discuss Coast Range geology in print.

The review, in spite of the peculiar friendliness which animates it, and the voluminous *beliefs* and *opinions* with which it is inflated, contains some more serious elements of scientific criticism. Were my work in this field closed, I should feel it incumbent upon me to reply promptly. As my studies are, however, still in progress, so far as my limited time will permit, and as I hope on a future occasion to offer a further contribution to the geology of the central Coast Ranges I shall for the present defer the discussion of the points raised by my critic, and so, conceding nothing, avoid a controversy distasteful to me by reason of the personal feeling which vitiates its scientific worth.

ANDREW C. LAWSON.

BERKELEY, Feb. 26, 1897.

# NOTE ON THE GEOLOGY OF SOUTHWESTERN NEW ENGLAND.

In two papers entitled respectively, "On the Geological Structure of the Mount Washington Mass of the Taconic Range" and "On the Geological Structure of the Housatonic Valley lying East of Mount Washington,"[1] the writer has considered the limestone and schist masses of the area covered by the papers to be each separable into two formations, the limestone alternating with the schist and together comprising a series corresponding to that of Greylock some thirty-five miles to the north. This conclusion was reached from both lithological and structural considerations. The strongest reason for believing the full Greylock series to be present was the apparently anticlinal character of certain ridges of Berkshire schist. These ridges were represented as Riga schist (equivalent to Berkshire) and the limestone surrounding them as Egremont limestone which was supposed to correspond to the Bellowspipe limestone of Greylock. The areal continuity of this limestone with the limestone of Canaan, which immediately overlies the Cambrian quartzite and must therefore be considered Stockbridge, was explained by an important strike fault which can be shown to follow approximately the course of the Housatonic River for a considerable distance.

As fully explained in the first of the papers the area is one in which the structures indicating bedding have been largely effaced during the folding and new structures have been developed. In only a few instances has it been possible to obtain a sufficient number of reliable dip observations to determine with certainty the nature of the folding.

Since the papers above referred to were written further study has been given to the area in the effort to find a locality where

[1] Journal of Geology, Vol. I, pp. 717–736, 780–802.

the structure of the apparently anticlinal ridges of Berkshire schist could be determined with certainty. In the ridge of schist immediately to the south of the east Twin Lake in the township of Salisbury and in the mass of Tom Ball near Housatonic village the observations obtained have been sufficiently numerous and reliable to show that the folds are either overturned anticlines with easterly dipping axial planes or nearly recumbent *fanned* synclines with the axial planes inclined to the eastward. In Tom Ball attempts to follow the fold in the direction of the strike taking note of the pitch of the axis with a view of determining whether the surrounding limestone goes below or above the schist on the end of the fold, afforded no positive results. On the other hand the ridge south of Twin Lakes was followed southward into Watawanchu Mountain where the limestone can be seen to pass under the schist on the end of the fold. This latter locality is therefore a crucial one and shows that the apparent anticlines of schist are nearly recumbent synclinal folds with the necks compressed so as to produce a fan structure.

Turnip Rock in Salisbury was shown to be a syncline by Dana, and the writer has referred to it as one of the best observed localities to show the superior position of much of the schist (formerly called Everett schist) to the valley limestone. A study in detail of this hill shows that it is made up of a fold similar to those of the apparent anticlines, though here the limestone completely surrounds the hill and dips so as to form a shallow basin. The peculiar character of the fold is only revealed in the dips of the schist high up on the slopes of the hill.

In view of the definiteness of the above determinations it is best to substitute for the local terms Canaan limestone and Riga schist the terms Stockbridge limestone and Berkshire schist, which they were supposed respectively to represent and which they are now shown to be. The Egremont limestone should be replaced by the Bellowspipe limestone, which it was thought to be, and its distribution is limited to that of the calcareous schist and limestone of the summit plain of Mt. Wash-

ington, the limestone of the Housatonic Valley being included in the Stockbridge limestone. The Everett schist which is here shown to be identical with the Riga schist, should like it be mapped as Berkshire schist. I am glad to be able to acknowledge my indebtedness to Dr. Van Hise for much valuable assistance in reaching a definite settlement of this problem.

WM. H. HOBBS.

# STUDIES FOR STUDENTS.

## DEFORMATION OF ROCKS. V.

### SUPPLEMENTARY NOTES.[1]

*Separation of the outer part of the earth into zones.*— In dividing the outer part of the crust of the earth into an upper zone of fracture, a middle zone of combined fracture and plasticity, and a lower zone of plasticity,[2] three factors should be taken into account, (1) the depth of burying, and therefore the vertical pressure, (2) the relative strength and plasticity of the materials, and (3) rapidity of deformation.

If the last two factors were constant, as a result of the first factor the zone of plasticity would be directly below the zone of fracture with a possible narrow transition zone. The greater the strength of materials, and the greater the rapidity of deformation, the deeper is the zone of plasticity. The weaker and more plastic the materials, and the slower the deformation, the nearer the surface is the zone of plasticity. However, as these factors vary greatly there is a wide middle zone of combined fracture and plasticity. Some rocks may be deformed by plastic flow very near the surface, and others by microscopical fracturing at a great depth. As illustrating this, a bed of mud may be deformed without fracture at or near the surface. Upon the other

[1] Figure 101, on page 595, of my paper on the Principles of North American pre-Cambrian Geology, in the Sixteenth Ann. Rept. of the U. S. Geol. Survey, Part I, was taken from Dr. Carl Futterer. The statement, "After Futterer" was in the manuscript list of illustrations, but by mistake this was omitted in printing.

[2] (A) Principles of North American pre-Cambrian Geology, by C. R. VAN HISE; with an appendix on Flow and Fracture of Rocks as related to Structure, by L. M. HOSKINS. Sixteenth Ann. Rep. U. S. Geol. Surv., Part I, 1896, pp. 589–603.

(B) Deformation of Rocks, by C. R. VAN HISE. JOUR. OF GEOL., Vol. IV, 1896, pp. 195–213.

hand the strongest, brittlest rocks in the deepest zone observable may be partly deformed by complex fracturing along intersecting shearing planes, but, however, without spaces between the particles. In the deepest seated zone the fracturing of the mineral particles may be so uniformly distributed as to give slight undulatory extinction only, the ultimate particles between which differential movements have occurred or differential stresses are at work not being discriminated as such even with the most powerful objective. However, in some of the deformed strong rocks even such stress effects as undulatory extinction are not marked, and in this case, the material must have been largely released from strain, just as in the case of viscous liquids which for a time after deformation show stress effects, but which later free themselves from them. Such profound changes are believed to involve recrystallization, water being the agent through which alteration took place.

It is also conceivable that where the deformation is very slow, even strong, brittle rocks may be deformed by plastic flow comparatively near the surface. But as shown by deep tunnels, some of which have in places a superincumbent load of rock a mile thick, if flow does occur, it is very slow indeed. This, too, is in spite of the fact that a tunnel is substantially a cylinder, very long in comparison to its width, and therefore that if the stress amounts to one half of the elastic limit of the rock, flowage would result.[1] But in estimating the stress in the case of tunnels, it is to be considered that the mountain mass does not have vertical but sloping sides, and hence is really a flat cone. While from the above it is clear that the superincumbent weight of thousands of feet of rock is not sufficient to cause flowage in very strong rocks, it is equally certain that in softer rocks, such as shale and coal, flowage occurs under much less weight than this, as shown by the creeping and closing of some galleries in mines, which at a depth of one thousand feet or less, have from time to time to be cut out, so as to compensate for the creeping flow which has tended to close them.

[1] Loc. cit., (A), pp. 592; (B), p. 199.

Notwithstanding all of the foregoing difficulties and qualifications, it is still possible in the field to place most masses of rock somewhat definitely in one of the three zones, the predominant phenomena in most cases of tolerably homogenous rocks being either fracture or flowage, while in heterogeneous rocks of many districts fracture and flowage are both of importance.

*Plastic flow produces folding.*—It has been pointed out that the zone of plastic flow is in the zone of folding.[1] Under the conditions of flowage, where the laws of hydrodynamics obtain, there is a constant tendency to approach equilibrium. But because rocks are heterogeneous both in strength and magnitude of elements, this tendency results in very complex flowage, and the resultant forms of deformation include all varieties of rock folds. However, this complexity of flow presents no exceptions to the laws of hydrodynamics.[2] At any moment, for any homogeneous small plastic area, for any forces which may be at work, the deformation obeys the laws of hydrodynamics, *i. e.*, the material moves in the direction of least stress.

*Complex folds.*—It has been stated that the two sets of simple folds making up complex folds have a tendency to be at right angles to each other. This appears to follow as a necessity from the laws of mechanics.[3] Any number of pressures in all directions may be analyzed into three pressures at right angles to one another, these being maximum, mean, and minimum pressures. At the outset of the action of the folding forces, because the beds and formations act as transmitters of forces, there will be a tendency for two of the principal directions of stress to be parallel to the bedding, and the other of the principal directions of stress to be normal to the bedding. Even after the layers are inclined it will still be true that at any moment the tangential forces may thus be analyzed. Thus we have the explanation of rectangular systems of folds in districts of complex folding. The closer folds are at right angles to the greater horizontal pressure, and the more open cross folds are at right

[1] Loc. cit., (A), p. 594; (B), p. 202. [3] Loc. cit., p. 627 (A); (B) p. 345.

[2] In my previous articles on deformation by plastic flow I have used the word *hydrostatic*. The word *hydrodynamic* should have been used.

angles to the less horizontal pressure. It may be that the tangential forces in either direction constitute a vertical couple, and in such cases monoclinal folds may be produced.[1]

While for a given district it may be assumed for definite areas that the average direction of the maximum and mean forces remain the same for considerable intervals of time, it does not follow that in the adjacent districts, or in another part of the same district, the relative values of these may not be reversed, and thus the direction of the closer folds for one part of the dis-district be that of more open folds of another part of the district.

Moreover, as a result of the action of the formations as transmitters of forces, plications may be formed intermediate between the two prevalent directions. Minor plications deviating from the general directions of folding are particularly likely to be seen when the two tangential forces are about equal, thus forming domes, and at places where a strong formation plunges below the surface as a result of the cross folding. In such cases the strata, especially the weaker strata, may be in a set of radial minor plications, mantling around the dome or mantling around the plunging mass of strong material. At each point the axes of the minor plications represent the dip of the slopes of the dome or of the stronger bed. Such plications result from the necessary readjustment between the beds. To illustrate—when a piece of leather is placed upon a hemisphere, it will fit closely at the top, but cannot be made to fit along the sides of the hemisphere unless portions be cut out. In nature the rocks cannot be cut out, and as a consequence we have the radial flutings, which in the case of anticlines plunge away from the crest, and in the case of synclines plunge toward the trough. These flutings, and the consequent radiating or converging character of the minor axial planes, are frequently of great assistance in determining whether a given mountain mass is an anticlinorium or a synclinorium. However, it appears that the arrangement of these flutings is no exception to the general law, for there is always a marked tendency for strong beds to decompose the

[1] Loc. cit., (A), pp. 626–627; (B), pp. 343–345.

forces into components parallel to their strike and dip at any given point, and thus the axes of these minor plications would correspond to the local directions of greater and less thrust.

*Monoclinal anticlines and synclines.*— In regions of close monoclinal folds, the axial planes of which have a low dip, and especially if there be a little fanning, it may be difficult to discriminate between anticlines and synclines. This principle is well illustrated by the relations of the limestone and schist in the Housatonic

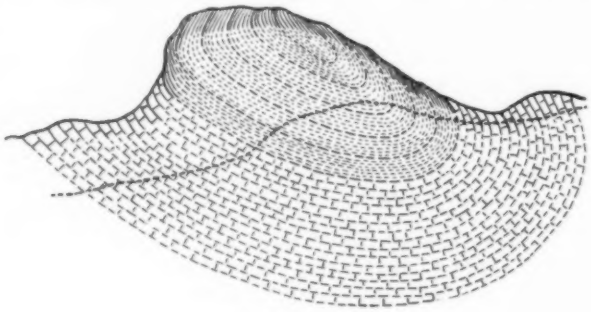

FIG. 1.

Valley. The Stockbridge limestone composes the lowlands for the most part. Rising from the lowlands are numerous schist ridges, varying from small hills to mountains such as Tom Ball and Lenox, the summits of which are from several hundred to a thousand or more feet above the valley. These schist ridges are, in fact, synclines which rest upon the limestone. However, observations of the dip across the ridge would in many cases lead to the conclusion that they are anticlines, as upon opposite sides of the ridge there is a divergence downward in the dip (Fig. 1). Of course dip of bedding is here meant,— not dip of schistosity, which, while variable, dips with considerable regularity to the east. This anticlinal appearance is well illustrated by the hill called Turnip Rock and the larger hill known as Barack M'Teth, and also by Tom Ball, all in, or partly in, the area covered by the Sheffield topographic sheet of Massachusetts. In each of

these cases, if the dips of the schist observed in crossing a ridge were alone considered, the ridges would unquestionably be called anticlines. Also if the layers of limestone immediately adjacent to the schists were taken into account, the same con-

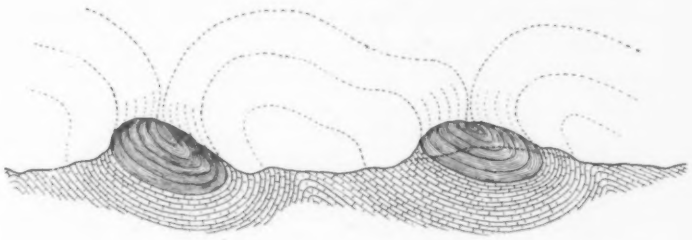

FIG. 2.

clusion would be reached (Fig. 2). While the dips in each case, both on the east and west sides of the ridges, are generally to the east (locally west dips are formed on the west sides of the ridges), on the east side of each ridge the dip is flatter than on the west side, thus making a divergence downward. Fortunately, however, in the case of Turnip Rock, the limestone at both the north and south ends of the hill is traced to the schist, and is found to plunge under it. In fact, at the south end of the mountain the limestone can be almost continuously traced under the schist, and seen to bend suddenly from an almost flat position to its overturned position. A study of Barack M'Teth and other mountains and their relations shows that Turnip Rock is unquestionably a type of the remainder of the ridges of the district. They are nearly recumbent, slightly fan-shaped synclines. In the areas between the schist ridges the limestone has for the greater part of the distances a continuous rather moderate dip to the east. It is only near the east side of the ridges that the sudden turning over of the anticline may be found. A section through two synclinal schist ridges, with intervening limestone, is generalized in Fig. 2. It is to be noted that if the plain of denudation had cut somewhat lower, so as to remove

all but remnants of the schist (see dotted, lines Figs. 1 and 2), these lower parts would appear as ordinary synclines, with little or no evidence of fanning. Indeed, in the case of a number of the schist ridges in the Housatonic Valley, erosion has so far advanced as to have left only the lower part of the synclines. Thus one who studies two adjacent schist ridges cut to different depths and overlooks the intermediate anticline of limestone, which is difficult to discover because of the poor exposures, might infer that one is an anticline and therefore is overlain by the limestone, and that the other is a syncline and is therefore underlain by the limestone. (See Fig. 2.) The conclusion would thus be reached that there are two schist formations, one of which is older than, and the other of which is younger than, the limestone, whereas there is only a single schist formation, and all ridges whether apparently anticlines or synclines, are parts of synclines of the same type and all overlie the limestone.

*Positions of cleavage in anticlines and synclines.*—In another place I have given the general law:[1] "On opposite limbs of a fold the cleavage usually dips in opposite directions. Upon opposite sides of an anticline the cleavage usually diverges downward, and on opposite sides of a syncline it usually converges downward." No instance of this principle was given. Since this was written it has been found that this principle is well illustrated on Mount Barack M'Teth above mentioned, upon the southern part of Mount Washington in Massachusetts, and upon all of the various synclines of Manhattan schist of Manhattan Island and of the area to the northward. In each of these cases the areas are synclinal, and in all of them the cleavage on opposite sides of the ridges converges downward. Subordinate anticlines of the Manhattan schist, in synclinoria which illustrate the above principle, show the reverse principle, that is, the cleavage diverges downward upon opposite sides of the minor anticlines. This principle is also illustrated at the anticline of Fordham gneiss a short distance south of Harlem Bridge. In many of these cases the folds are monoclinal, and

[1] Loc. cit., (A), pp. 649–650; (B), p. 474.

in some of them the cleavage is also monoclinal, but still shows divergence or convergence downward upon opposite sides of a fold according to the law. In the monoclinal syncline the monoclinal cleavage on opposite sides of the limb converges downward, and in the monoclinal anticline the monoclinal cleavage on opposite sides of the limbs diverges downward.

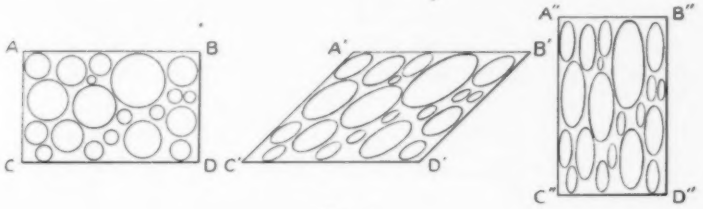


FIG. 3.

It may be suggested that in cases where metamorphism has gone so far that it is difficult to determine bedding this principle of the convergence downward of cleavage on opposite sides of a syncline, and divergence downward of cleavage on opposite sides of an anticline, may be used to determine whether a series of folded exposures are anticlinal or synclinal. In another case, where the bedding is somewhat obscure and dips difficult to get, it may be used as confirmatory evidence of the observations made upon the bedding.

*Relations of cleavage produced by shearing to shortening.*— In the production of cleavage as a result of simple shearing, Professor Hoskins has pointed out that the cleavage approaches parallelism to bedding faster than does a line originally normal to the bedding.[1] As the actual positions of the cleavage resulting from definite shears and the relations of original circles to equivalent flattened ellipses (Fig. 3) are matters of some practical importance in the field, Mr. E. C. Bebb was asked to tabulate the positions of the major axes of the flattened ellipses, the values of

[1] Flow and Fracture of Rocks as Related to Structure, by L. M. HOSKINS. Appendix to Principles of North American pre-Cambrian Geology, by C. R. VAN HISE, Sixteenth Ann. Rept. U. S. Geol. Surv., Part I, 1896, pp. 870–871.

the major and minor axes of the ellipses compared with those of the diameters of equivalent circles, the ratios between the last two, and the ratio between the diameters of the original circles and the minor axes of the equivalent ellipses, for rotations of a vertical line at intervals of 5°.[1] This table is as follows, the positions of the major axes of the ellipses being calculated to the nearest 1′:

| 1 Deviation of a vertical line from the perpendicular, as a result of simple shearing | 2 Angle between major axes of ellipses and the vertical, resulting from shearing circles | 3 Complements of the angles given in (2) or the dip of the cleavage | 4 Length of minor axes of ellipses compared with diameters of original circles | 5 Length of major axes of ellipses compared with diameters of original circles | 6 Ratios between minor and major axes of ellipses | 7 Ratios between minor axes of ellipses and diameters of original circles |
|---|---|---|---|---|---|---|
| 5° | 46° 15′ | 43° 45′ | .957 | 1.045 | 1 : 1.091 | .957 : 1 |
| 10 | 47 31 | 42 29 | .916 | 1.092 | 1 : 1.193 | .916 : 1 |
| 15 | 48 49 | 41 11 | .875 | 1.143 | 1 : 1.306 | .875 : 1 |
| 20 | 50 10 | 39 50 | .834 | 1.198 | 1 : 1.436 | .834 : 1 |
| 25 | 51 34 | 38 26 | .794 | 1.260 | 1 : 1.587 | .794 : 1 |
| 30 | 53 3 | 36 57 | .752 | 1.329 | 1 : 1.768 | .752 : 1 |
| 35 | 54 39 | 35 21 | .709 | 1.410 | 1 : 1.987 | .709 : 1 |
| 40 | 56 23 | 33 37 | .665 | 1.504 | 1 : 2.262 | .665 : 1 |
| 45 | 58 17 | 31 43 | .618 | 1.618 | 1 : 2.618 | .618 : 1 |
| 50 | 60 24 | 29 36 | .568 | 1.759 | 1 : 3.096 | .568 : 1 |
| 55 | 62 46 | 27 14 | .515 | 1.943 | 1 : 3.775 | .515 : 1 |
| 60 | 65 27 | 24 33 | .457 | 2.188 | 1 : 4.787 | .457 : 1 |
| 65 | 68 30 | 21 30 | .394 | 2.538 | 1 : 6.446 | .394 : 1 |
| 70 | 71 58 | 18 2 | .325 | 3.073 | 1 : 9.446 | .325 : 1 |
| 75 | 75 55 | 14 5 | .251 | 3.983 | 1 : 15.868 | .251 : 1 |
| 80 | 80 17 | 9 43 | .170 | 5.842 | 1 : 34.30 | .170 : 1 |
| 85 | 85 2 | 4 58 | .0866 | 11.517 | 1 : 134.9 | .0866 : 1 |

The facts of this table are graphically represented by Fig. 3 for a rotation of a vertical line amounting to 45°.

It is of interest to note that the table shows that with the least possible shearing the greater diameter of an ellipse is inclined 45° to the vertical, or 45° is the smallest or limiting

[1] The position of the major axis of a flattened ellipse with reference to the position of a vertical line rotated a definite amount, and vice versa, resulting from shearing, may be calculated from the following relation: The tangent of twice the angle between a horizontal line and a rotated vertical line (complements of the angles of column 1) is equal to twice the tangent of the angle between a horizontal line and the corresponding major diameter of the flattened ellipse (angles of column 3). Assigning any possible value to either angle, the other is easily calculable.

angle. That is to say, the highest possible dip which a cleavage can have as a result of simple shearing is 45°. The greater differences between the positions of the rotated vertical lines and the major axes of the flattened ellipses result from the smaller rotations and the largest or limiting value is 45°. The differences between the positions of the rotated verticals and the corresponding major axes of the flattened ellipses rapidly diminish in amount with the increased rotation of the verticals, and for rotations of 75° and above the differences are less than 1°. The last column (7) shows the relative efficiency in the production of cleavage of simple shearing, as compared with shortening in a single direction with consequent elongation in another direction. From this column it is seen that shearing which rotates the vertical by 10° is equivalent to a shortening of somewhat less than one-tenth ; that a rotation of the vertical of 20° is equivalent to a shortening of about one-sixth ; that a rotation of the vertical of 30° is equivalent to a shortening of about one-fourth ; that a rotation of the vertical of 45° is equivalent to a shortening of a little more than one-third ; that a rotation of 60° is equivalent to a shortening of a little more than one-half ; and that a rotation of 75° is equivalent to a shortening of about three-fourths. Of course the ratios between the minor and major axes of the ellipses are the same for shortening and corresponding shearing.

In the actual production of cleavage, shortening and rotation are combined in various proportions. It would be interesting to know certainly the amount of simple shearing and of shortening which is necessary to produce ordinary slaty cleavage. I have pointed out in another place[1] that cleavage develops more largely from the formation of new minerals than from the flattening of the old mineral particles, and I am inclined to believe that a very moderate amount of shearing or shortening is sufficient to produce the structure imperfectly — possibly as little as that represented by a shortening of 10 per cent., or a rotation of the vertical of about 10°. Upon the other

[1] Loc. cit., (A), p. 635; (B), pp. 451-453.

hand it is certain that in many schists the actual shearing and shortening is several times this amount. The major axes of the flattened ellipses in the extreme phases of deformation are sometimes from 10 to 20 times as long as the minor axes.

*Relations of cleavage and fissility to faults.* — It has been explained that the shearing resulting in cleavage or the shearing resulting in fissility may accomplish the same kind of deformation as does thrust faulting.[1] It is equally true that if, after a fissility is produced, the rocks are under conditions of tension, numerous minor slips along planes of fissility may result, the effect of which is equivalent to normal faulting. In different districts, in the Appalachians, for instance, at various places in the Cranberry sheet, at Blowing Rock, N. C., and in Georgia and Alabama, there have been observed during the past season the results of widespread, somewhat uniformly-spaced, differential movements between laminæ at intervals varying from $\frac{1}{32}$ to $\frac{1}{4}$ of an inch. In numerous cases, as a result of these differential movements, the formations of district are brought into the same abnormal positions as would be produced by ordinary normal or thrust movement. The many slight differential movements equivalent to thrust faults, so far as my obervations have gone, are more frequent than the many slight differential movements equivalent to normal faults. In the Cranberry area a granite-gneiss, normally belonging below the Linville series, is brought forward on the north and south sides of the area by innumerable minute movements between the laminæ, to a position above the Linville series. The same sort of irregular distribution due to minute differential movements is seen in the formations of the Linville series itself. In these cases one cannot find a certain plane, or even a narrow zone, and say that here a fault has occurred. However, it is certain that in a zone of considerable width a differential movement has occurred as great as could be accomplished by a great normal or great thrust fault. For this particular form of deformation spread over a considerable area, which does not have the clear cut character of an ordinary fault,

[1] Loc. cit., (A), pp. 659–660; (B), pp. 597–598.

and yet accomplishes the same mass deformation, the term *distributive fault* is proposed. There may be distributive normal or tension faults and distributive thrust or compressive faults.

*Relations of joints to bedding.* — Joints have been classified into tension joints and compression joints.[1] Tension joints ordinarily form nearly normal to bedding. This results from the fact that the layers act as transmitters of forces, and that at any given place one of the principal directions of stress is ordinarily nearly normal to the layer, and the other two principal directions of stress lie in the plane of the layer. That this tendency to thus decompose the forces exists cannot be doubted. That it would be the controlling tendency in the majority of cases could not be asserted from analysis alone. However, examinations of various regions during the past season has shown me that this is often a controlling tendency, and that tension joints ordinarily do form nearly at right angles to the bedding. It has already been explained that in regions of simple folding there is one set of tensile joints,[2] and that in regions of complex folding there are two sets of tension joints. The reverse statement may be made,—that is, that where there are two sets of intersecting tension joints at right angles to each other normal to bedding, these are evidence that the region is one of complex deformation.

Compressive joints, in contrast with tensile joints, because formed in shearing planes, are ordinarily inclined to the bedding.[3] This also results from the fact that one of the principal directions of stress is usually nearly normal to bedding. Supposing the maximum stress to be in the direction of the arrows of Fig. 4, the mean stress at right angles to the plane of the figure, and least stress in the plane of the figure and at right angles to the maximum stress, in other words normal to the bedding, the position of the joints will be as shown, their planes being normal to the figure in which they are represented in section. This results from the fact that the direction of least stress

[1] Loc. cit., (A), pp. 668-671; (B), pp. 609-613.

[2] Loc. cit., (A), p. 669; (B), pp. 609-610,.

[3] Loc. cit., (A), p. 671; (B), p. 613.

is that of relief, and after rupture the differential slipping between joints will cause shortening in the direction of maximum stress and elongation in the direction of minimum stress.

When it is remembered that all the forces at work at any place may be decomposed into three principal directions of stress

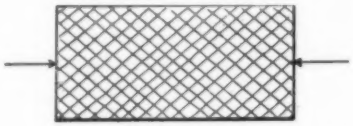

FIG. 4. Cross-section of a bed showing joints.

at right angles to one another, it would seem to follow that there would ordinarily be produced only two sets of compressive joints at the same time. To suppose that more than two sets are simultaneously produced would require that the ultimate strength was exceeded at the same moment in two of the principal directions of stress, and this is probably not a common case. One would expect, if the forces in two of the principal directions of stress are equal or nearly so, that the ruptures would be conchoidal, and this may be the explanation of some of the cone-in-cone structures. Supposing the compressive stresses to be unequal, the ruptures are produced by the maximum stress, and any one of three strains may result: (1) shortening in one direction, (2) simple shearing, and (3) shortening in one direction combined with shearing. In the first case, that of shortening in one direction and consequent elongation in a single direction, there are produced two sets of joints, but not exactly at right angles to each other. The maximum force probably bisects the acute angles (Fig. 4).[1] Subsequently, however, by differential movement between the fractured parts, it is possible that the joints may be so rotated as to change the originally acute angles to obtuse angles. The two sets of joints would only be at right angles in case the rotation stops at a definite stage. In the second case, that of simple shearing, there is one set of compressive joints

[1] Loc. cit., (A), pp. 643, 873; (B), p. 465.

and one set of tensile joints. The compressive joints lie near the longer diagonal of the deformed rectangle, and the tensile joints are near the shorter diagonal (Fig. 5). Ordinarily the former are closer together than the latter. In the third case (1) and (2) are combined; whether there are two sets of compression

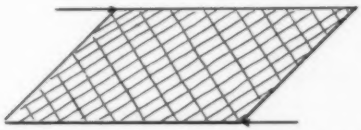

FIG. 5. Cross-section of a bed showing joints.

joints, or one is a compression and the other a tension set, will depend upon the relative amounts of shortening and shearing.

After rupture occurs as the result of tensile or compressive forces, producing one or two sets of joints, if the force in the plane of bedding at right angles to the first direction of force accumulates so as to exceed the ultimate strength of the rock, it may produce other sets of joints. In case this force is tensile, one set of joints will be produced in the normal planes. If it is compressive, any of the three cases of compressive joints above given may occur. Thus there may be produced three or four sets of intersecting joints.

From the foregoing, the criteria by which tensile and compressive joints may be separated are easily inferred. Tensile joints are ordinarily nearly normal to bedding. Compressive joints are ordinarily much inclined to bedding. Between the walls of tensile joints there is ordinarily a small space; the walls of compressive joints are, or were originally, pressed closely together. The walls of tensile joints are not likely to show differential movements nor slickensided surfaces; the walls of compressive joints generally show slight differential movements and more or less slickensided surfaces.

*Relations of joints to folds.*— Many cases of apparent bending of the strata are really not due to bending but to jointing. It has been pointed out that the first is a phenomenon of the zone of flow

age, and the second is a phenomenon of the zone of fracture. The special point to which I wish here to call attention is that as a result of the displacements of jointing, the strata may appear in generalized curves of anticlinal and synclinal character (Fig. 6). In various districts rocks which have not been so

FIG. 6.

deeply buried as to be in the zone of flowage appear to be in anticlines and synclines. In these cases it is believed that the phenomena are explained as above suggested. This principle is illustrated by the slightly undulating rocks of the upper Mississippi valley. Cutting these everywhere, and in many districts in two directions at right angles to each other, are systems of joints. These joints are phenomena of fracture, and the slight bowing, which one might represent as a fold, really is not a fold in the sense of the deformation of the strata by flowage, but is bowing as a result of very slight but abrupt changes in direction at the numerous joints, the general effect being to produce a folded appearance.

The apparent bowing due largely to jointing, so well illustrated in the Mississippi valley, is still more finely illustrated by the Allegheny Mountains. The limestones and sandstones of this mountain system, ordinarily regarded as deformed mainly by folding, are largely deformed by jointing. If the course of the strata be roughly platted, they will appear to be in continuous undulating curves. However, the rocks are everywhere cut by two intersecting sets of joints at right angles to each other, and it appears to be the case that the curved deformation is really not mainly that of folding, but mainly that of fracture

(Fig. 6). However, I would not assert that to some extent the material had not also flowed at various times before the stresses exceeded the ultimate strength of the rocks and ruptures occurred. Even if the apparent gentle curves of the strata can be more accurately represented diagrammatically by placing end to end a large number of broken lines with slight changes of direction, the curves indicated by the lines would have the forms of folds given under Analysis of Folds.[1] In the weaker shaly layers between sandstones and limestones the deformation is in many cases largely that of shearing, this being due to the differential movement between the two bounding strong layers. In the weaker layers the jointing is therefore in two diagonal sets.

In the case of the Mississippi valley it is clear that the stresses producing the jointing are locally still at work. For instance, at the combined rocks at Appleton,[2] a recent rupture occurred which was sufficient to make considerable displacements in the artificial works. Other cases of a similar kind have been given by Reade.[3] The foregoing cases show that the apparently horizontal rocks of the Palæozoic at the present time, are locally under such stress that when a slight amount of material is removed, and thus the beds not held so firmly in their position, the ultimate strength is exceeded and rupture occurs. Denudation is ever lightening the load of the strata, and from time to time, as a result of this, the abrupt deformations of jointing or faulting may occur. Before the time of rupture, it may be that the stresses, while not sufficient to produce rupture, may still surpass the elastic limit and result in slow flowage.

C. R. VAN HISE.

[1] Loc. cit., (A), pp. 603–633; (B), pp. 312–353.

[2] On a recent Rock Flexure, by FRANK CRAMER. Am. Jour. Sci., Vol. XXXIX, 1890, pp. 220–225.

[3] On the Cause of active compressive Stress in Rocks and recent Rock Flexures, by T. MELLARDE READE. Am. Jour. Sci., Vol. XLI, 1891, pp 409–414.

# *EDITORIAL.*

THE proposition to hold the winter meetings of the Geological Society of America in the city of Washington, as advocated by Professor Iddings, in the last number of this JOURNAL, is not without objections.

The members of the society may be classified in two groups; those engaged chiefly in investigation, and those who devote a part of their time to teaching. The interests of these groups differ and in arranging for the winter meetings of the society should have equal consideration. The members who reside in Washington are for the most part engaged in investigation, while the majority of the non-Washington members are occupied principally in teaching. It has been said by one eminent in our science, that the three requisites in geological training are travel, travel, travel. Under the proposed arrangement, members residing in Washington would be deprived in a measure of the opportunities which might otherwise be secured by them of seeing the laboratories, collections, etc., at various other centers from which geological information is disseminated. It is evident that it would be unfair to thus deprive our Washington friends of a means of education which might be of profit to them. Members of the society who are engaged principally in teaching, probably have as earnest desires to see the lecture rooms, laboratories, and collections of their colleagues and to learn their methods of teaching, as they have to study the methods of investigation carried on in Washington.

To enable both classes of members to profit by the opportunities afforded by our winter meetings and at the same time insure the desired attendance, it seems highly desirable that for some years to come, the meetings referred to should be held at the

various educational centers on the Atlantic coast between the Merrimac and the Potomac.

Without wishing to detract in the least from the debt of gratitude due the local committee which arranged for our convenience and comfort during the last Washington meeting, I wish to suggest that the lecture room of the National Museum is, in many ways, objectionable as a place in which to hold the sessions of the Geological Society. If the society elects to hold all winter meetings in Washington, a more suitable assembly room, and also rooms for the display of maps, collections, etc., as well as a conversation room, should be provided.

In reference to the expenses of the meetings being shared by the visiting members, as proposed by Professor Iddings in case the winter meetings are held regularly in Washington, it may be suggested that if each of the Washington members should subscribe an amount equal to the average traveling expenses of the visiting members, the expenses of the meeting could not only be met but a surplus would remain which might be devoted to publication or other useful purposes. I. C. R.

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It is gratifying to be able to call attention to the carefully made collections of rock specimens, which Mr. Oscar Rohn, of Madison, Wis., has prepared to illustrate the petrographical descriptions found in the writings of Pumpelly, Marvine, Irving, Van Hise, and Bayley, upon the famous mineral-bearing districts in the Lake Superior region. As is well known, collections of rocks representing the most important petrographical types at European localities may be obtained for purposes of study and instruction. But no systematic attempt has been made to furnish collections of typical rocks from American localities, with the exception of the proposed Educational Series which the United States Geological Survey has undertaken to gather together. A reason for this is in some cases evident, namely, the remoteness of the districts and the expense of collecting the specimens. The collection of Lake Superior rocks offered for sale by Mr. Rohn is a step in the direction of such systematic

collecting, and places within reach of students and teachers of petrology material of the highest value, making it possible to follow intelligently the descriptions by the investigators already named, of the rocks in the Keweenaw, Penokee, and Marquette districts. The collector had the advice and counsel of Professor Van Hise, who vouches for the care with which the work has been carried on. Not the least valuable part of the undertaking is the furnishing of a catalogue in which specific references to the monographs of the region are given in connection with each specimen. The hand specimens are accompanied by chips from which thin sections may be prepared. The enterprise is to be heartily commended, and it is hoped that a sufficient number of petrologists will avail themselves of the opportunity of securing the collections to compensate Mr. Rohn for the time and money expended upon them. J. P. I.

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EMM. DE MARGERIE and his colaborers of the bigliographical committee of the international congresses of Washington and Zürich merit the warmest commendation of all working geologists for their disinterested labors in preparing and issuing a voluminous report under the title *Catalogue des Bibliographies Géologiques*. This is a book of 733 pages, and represents a very protracted and laborious search for bibliographical lists through a scattered and voluminous literature whose very unequal nature must have taxed the patience, skill and discretion of the committee to the utmost. The catalogue contains nearly 4000 references to bibliographies and works containing bibliographic references of some note, and thus it constitutes an invaluable key to geological literature. Provision has been made whereby those who were not members of the international congresses under whose auspices the work was prepared and published may secure it, together with the *Compte Rendu* of the Washington congress. The two volumes will be sent to individuals or libraries who will transmit $5 to the American member of the committee, G. K. Gilbert, of the United States Geological Survey, Washington, D. C. We would particularly urge upon libraries the purchase of this catalogue. T. C. C.

# *REVIEWS.*

*Geology and Mining Industry of the Cripple Creek District, Colorado.* By WHITMAN CROSS and R. A. F. PENROSE, JR. Extract from the Sixteenth Annual Report of the Survey, 1894–5. Part II: Papers of an Economic Character.

This report of Messrs. Cross and Penrose is to be classed as one of the most valuable of the publications on economic subjects issued by the Geological Survey. Though less elaborate and accompanied by fewer maps and illustrations than the bulkier monographs of past years, these considerations are largely offset by the timeliness of appearance and the handiness of the separate form in which the report was first issued. For no matter how great the intrinsic merit of the publication or the labor devoted to its preparation, its value lies to a great extent in its appearing at the right time and in a form suitable for ready use, and this particularly with a work relating to mining in a new camp. The report is the outcome of the joint field labors of the authors, prosecuted during three months in the autumn of 1894. It was written, printed, and issued in 1895, and the edition of the separates, as well as of the related Pikes Peak folio, was exhausted before the end of 1896.

The combined report covers about 200 pages of the large octavo size of the annual reports. It is illustrated by thirty-seven figures, seven plates, and one supplementary geological and topographic map which is inserted at the end of the report. The report is divided into two parts. The first, of 109 pages, by Mr. Cross, treats of the general geology and is in great part devoted to the important subject of the petrography of the district; Part second, by Mr. Penrose, deals with the mining geology of the district. The latter is exclusively the subject of this review, Mr. Cross' valuable report requiring the attainments of a specialist for adequate treatment.

Chapter I. of Mr. Penrose's report consists of a brief outline of the history of mining in the camp. Operations were practically begun

there in 1891. It is a very remarkable fact, this recent development in a well-known and traveled part of Colorado, within a stone's throw of what has been a much frequented summer resort for years. It is a fact of hopeful suggestion in relation to future discoveries of ore deposits in this country; but it is a fact also liable to much abuse by promoters as a warrant for the conclusion that gold ores may be found anywhere. It is likewise remarkable that the productive area is included within a district of only six miles square, the area of one township, and, further, as the map shows, a considerable part of this is unproductive ground. The surprising growth of the camp is illustrated by the fact that from an output of only a few thousand tons in 1891, the production increased in the years 1892, 1893, and 1894 to a total variously estimated at from $5,500,000 to $7,000,000. Since that time the growth has continued, and a conservative estimate for the year 1896, kindly furnished by Mr. T. A. Rickard, the geologist for the state, places the value of the production at $9,000,000, and others who are well posted estimate it between $8,000,000 and $9,000,000. During 1895 the value of the output was in the vicinity of $6,500,000. The total for the five years is thus about $22,000,000, or a little less than one-half of the present annual output of gold for the whole country.

It is to be regretted that more space could not have been given in the report to the statistics of the camp. The expense of an assistant for this special work would have been well repaid. The difficulty of obtaining complete and exact figures is undoubtedly great, if not insurmountable; but more could have been gathered than is contained in the two paragraphs of the report, which would have given some idea of the distribution of the shipments both as to time and localities. The difficulty is one which is met with to a greater or less extent in all mining camps of the West, and is partly due to a very natural desire of mine operators not to make their private business public property, especially where no unanimity of action can be secured. Yet such facts are highly valued by mining men and the public and are valuable guides to investors. The gathering of complete statistics would do much towards placing mining on a sound basis. Public effort could well be exerted in this direction and provision made for the collection of such statistics by judicious legislation.

Chapter III is devoted to the ores of the camp, or more precisely to the minerals of the ore deposits. As Dr. Penrose says in his summary, the ores consist of the country rock, more or less completely

replaced by quartz, with fluorite, opaline silica, and kaolin, and containing iron pyrites, and other sulphides, as well as various other minerals in limited quantities.

Gold is the only metal which occurs in amounts of commercial value. It is found normally as a telluride, or in a free state as a result of the oxidation of the former. It is possible that some of the gold is present as auriferous iron pyrites, but this must be quite rare as most of the pyrites is valueless, and, as a rule in the camp, rock impregnated with this mineral is considered of little significance.

The free gold appears to be confined to zones of oxidation and these frequently extend to depths of several hundred feet. It is generally in a very fine condition, but sometimes pieces up to a quarter of an inch in size are found. It is usually rusty, but is otherwise remarkably pure, with hardly any appreciable silver, even less than is found in the telluride ores. The telluride of gold appears to be principally the mineral calaverite, according to examinations made by Mr. W. F. Hillebrand and Dr. S. L. Penfield; but there is probably also some sylvanite and other compounds.

Silver occurs only in very small quantities in most of the ores, though at the Blue Bird and a few other mines it has been found in considerable amounts, though not enough to make any showing in the production of the camp.

As an accessory mineral, galena has been found at a number of places, but in small quantities. Some spahlerite occurs at a few mines. Copper minerals are extremely rare, as are antimony compounds also. Fluorite is common in many ores and is frequently prominent by reason of the coloration it gives to the rocks. It is sometimes intimately associated with quartz. Quartz is the most common secondary mineral. It is sometimes found in bodies and occurs also as well-defined quartz veins, but more frequently it is homogeneously disseminated throughout the ore or country rock, simply making them harder. Such silicified rock is often confused with dikes by the miners.

Kaolin is common along fissures, resulting from decay of the feldspar of the eruptives; it is either white or stained a brown or black color. Calcite is not abundant and occurs lining the face of rocks or filling small cavities. Gypsum, though not of frequent occurrence, is found in bodies of some size in one mine. Barite and other minerals also occur in small quantities.

Superficial alteration of the rocks is apparent to depths of 300 and 400 feet with the usual effects of hydration, oxidation, and leaching.

The value of the ores shipped varies from $20 to $400 per ton; an average is perhaps between $50 and $85. During the first year's operation, the camp was essentially a shipper of high-grade ores. Recently, however, there has been a change with the establishment of a number of cyanide and chlorinating plants, which has reduced treatment charges to $7.50 per ton. It is to be feared, however, that an understanding between the managers of these plants will prevent a further reduction in these charges, if it does not cause an increase over the above rate. It is of great importance to the future of the camp that low freight and treatment charges be reached and maintained as otherwise great quantities of low-grade ores will have to be thrown aside. Any such movement, therefore, to maintain high charges is to be opposed and may seriously damage the camp.

Chapter III deals with the mode of occurrence of the ores. This subject is one of special value and interest here. It is well summarized in the statement of the first paragraph, which is to the effect that the ores generally occur in fissures in the country rock, which usually represent slight faulting and that the veins have been formed mostly by replacement along these fissures and not by the filling of open gaps. Indeed, there is often no cavity recognizable and little, if any evidence of one ever having existed, the solutions apparently having filled the imperceptible space between the flat joint or fault planes of the rock, the gold minerals having been deposited on the surface and the rock itself having been merely silicified. Thus, in these deposits, the scrapings from such surfaces often run very high in gold, while the rock itself is valueless. This is a very peculiar form of deposit and is almost exclusively confined to this district.

The deposits occur in a region of Tertiary volcanic breccias or tuffs. The breccias are cut by numerous bodies of intrusive eruptive rocks, such as phonolite and andesite, and they also surround eruptive masses which are older than the breccia. The latter are themselves surrounded by what Cross terms the granite-gneiss complex of the Colorado range. The dikes intersect all of these rocks, passing from granite into breccia, and they also intersect each other. They are evidence of several epochs of fissuring. The veins also intersect all these rocks in their courses. The vein fissures seem to be later than the dikes, though some were apparently formed at the same time.

The courses of both vary from northeast to northwest, but there are exceptions to this rule.

The fissures are not open gaps, as already stated, but are closed lines of fracture along which replacement has occurred. In Dr. Penrose's words: "Sometimes there are two or more main parallel cracks or fissures and numerous minor ones, while very commonly the zone of fracturing seems to be represented by no especially well-defined break, but by numerous parallel or approximately parallel cracks, each of about the same magnitude and from a fraction of an inch to several feet apart." . . . . "In fact the district may be regarded as an area intersected by numerous zones of fissuring which are separated by an area of less marked but very noticeable fissuring." The ore is found lining both sides of the fissures.

Faulting is evidenced by grooves and slickensided rock surface. The movements were small in amount, the greatest observed being between twenty and twenty-five feet.

The minerals of the ore bodies are generally promiscuously arranged, the ore usually being simply the country rock containing greater or less amounts of secondary minerals. Ore is found along some of the fissures or cracks, while others, almost identical in appearance, are barren. These fissures are often taken by miners for vein walls beyond which no ore will be found. They hence neglect to cross cut. Dr. Penrose gives a valuable suggestion in advising miners not to be misled by these apparent walls, as valuable deposits will often be found within a short distance beyond them. As an illustration, in a mine operated by the writer about a dozen such fissures, variously mineralized, were encountered in a cross cut of about 100 feet.

A noticeable feature of this camp is that the veins follow the dikes, either in contact, or more commonly in proximity to them. Sometimes they cross the dikes and follow them on different sides. The association of dikes and veins is a fact well known by mining men and the presence of a dike, especially of phonolite, causes a claim to be held in much higher estimation.

In their mode of occurrence the dikes and fissures give evidence of a limited erosion of the district. Thus their upper parts often differ markedly from their deeper parts. "The dip near the surface is frequently at a different angle from that at a depth, and veins which occur in one well-defined fissure at a depth sometimes fork near the surface and appear in separate outcrops. Both these phenomena can

be attributed to the fact that at a depth the fissures occupied by the dikes or veins were confined to the original line of breakage on account of the superincumbent pressure, while nearer the surface this pressure was relieved and numerous transverse breaks of more or less superficial character were encountered and the fissures were more easily deflected and divided."

It is of special importance with these deposits to distinguish between shrinkage cracks and fissures, both along dikes and elsewhere. The reason for this is that fissures are more persistent and likely to extend to greater depths than are shrinkage cracks.

The ore of the veins, as elsewhere, occurs in chutes. That is, certain parts of the fissures are barren while others contain ore of value. These chutes are of greater vertical than horizontal dimensions. They differ from the chutes generally recognized in other mining regions in being isolated bodies of ore along the fissure planes, rather than rich portions of otherwise clearly defined veins. They vary in breadth from one to several hundred feet, and from a few inches to several feet in width. Their distribution is not influenced by a difference in country rock, as that is uniform. They are probably due more to the location of cross fractures and fissures, and to localization of the ore-bearing solution. They are also affected by the distribution of the dikes.

Chapter IV treats of the source and mode of deposition of the ores.

The ore, Dr. Penrose concludes, was probably derived from both deep and shallow sources, from the whole area tributary to the fissures. An investigation of the actual gold contained in the country rocks was not made, but the metal doubtless exists in both the old and new formations, though he is of the opinion that the later eruptives were probably the most prominent source, as in them the conditions for concentration were best realized, as they were in the neighborhood of volcanic vents where the rocks were penetrated by hot waters impregnated with the mineral solutions. The solution and deposition of gold along with quartz from alkaline solution is readily understood, but the formation of the telluride of gold requires further investigation before it can be explained.

As regards the associated minerals, the fluorite was probably evolved from the phonolite magmas, in a volatile or soluble form, and acted on solutions carrying lime; if it was in the form of hydrofluorsilic acid, the association of the quartz with the fluorite is readily explained.

The fluorite has possibly also some connection with the presence of the telluride, as fluorite is common elsewhere where telluride ores occur.

The ore constituents were probably introduced in a liquid form, probably hot and probably hastened by steam and other vapors. The process of deposition was largely one of replacement; this may have been by chemical action or by deposition in minute cavities after the removal of constituents of the country rock. The latter Dr. Penrose thinks more probable. The deposition was caused principally by chemical reaction with other solutions rather than by reaction with the country rock.

It is to be regretted that a direct investigation of the problems of the source of the ores and their mode of deposition could not have been made. The study given to the subject is confessed to have been inadequate for final results. Though the conclusions reached by the author seem quite probable, they can be classed only as probabilities pending complete inquiry.

As a final criticism of this in so many respects valuable and excellent report, the cuts or the figures illustrating it might have been improved upon. They are somewhat too diagrammatic and most of them seem to be more of illustrations of the writer's ideas than actual sketches "from life" in the mine. This does not apply to all of the figures, nor to the small mine maps or plates which are inserted. These are excellent and appear to have been carefully compiled from the mine surveys.

ARTHUR WINSLOW.

TELLURIDE, COL.,
January 5, 1897.

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*Glacier Bay and its Glaciers.* By HARRY FIELDING REID. United States Geological Survey, 16th Annual Report, 1894–5, pp. 415–461. Plates LXXXVI–XCVI.

The studies of Muir glacier conducted by Professor Reid in the summer of 1890, and the results published in the *National Geographic Magazine*, Vol. IV, were continued and extended in the summer of 1892 and the results recorded in the report named above. During the earlier expedition, attention was restricted to Muir glacier and its tributaries, of which an excellent map was published; the later expedition had for its main object the exploration of the western extension of Glacier Bay with its numerous inlets and many glaciers.

The topographic work of the two expeditions referred to is combined on the map accompanying the report under review. This map showing ice, land, water, and moraines, is published on a scale of six miles to one inch, and embraces the entire extent of Glacier Bay, and its inlets. The extremities of all of the tidewater glaciers which discharge into the waters of the bay and the greater portion of Muir glacier with its many feeding ice streams, are also included. The numerous fine illustrations, reproductions of photographs, give a more graphic idea, especially of the characteristic features of the ends of the tide-water glaciers, than can be conveyed by written descriptions.

The general features of the shores and islands of Glacier Bay are described, special attention being given to the glaciers and inlets. Glacier Bay to the west of Muir glacier, has seldom been visited and was never surveyed previous to Professor Reid's careful examination. In this new field many important discoveries were made, and a number of geographical features named. Several glaciers were appropriately named in honor of distinguished European geologists.

There are eight glaciers to the westward of Muir glacier which discharge bergs into the waters of Glacier Bay. The extremity of each of these was examined and carfully mapped. The most extensive ice front of any of the nine tide-water glaciers, is that of the Grand Pacific at the extreme western extension of the bay. This glacier at present is divided by a high rockmass, in part island and in part nunatak, but presents an actual ice front 12,500 feet in length. A small recession will separate the ice from the land that divides it and increase the length of its magnificent ice cliffs to fully three miles. The combined extent of the ice frontage of the several tide-water glaciers of Glacier Bay, is between twelve and thirteen miles.

The hard geology about the shores of Glacier Bay and to a limited extent, of the mountains from which Muir glacier receives tributary glaciers, receives attention. Large areas of diorite, quartz-diorite, argillite, limestone, sand and gravel, are shown on a sketch map. A few fossils obtained from loose débris indicate that the limestones are of Carboniferous age.

The stratified gravel and sand containing stumps and trees, beneath the extremity of Muir glacier, and on the adjacent shores, to which considerable attention had previously been given by Professor Reid and others, were again studied and fresh observations made which sustain the conclusion that gravels, etc., were laid down by streams from the

glaciers during a period of recession and overridden when the ice readvanced. Some important modifications of this general history are suggested.

Among the many interesting results reported, are observations on variations in the extension of Muir glacier between 1880 and 1892. Records of the position of the extremity of the glacier in 1880, 1886, and 1890, showed an apparently continuous recession of about 250 yards a year, but in 1892 the ice front had advanced on an average of approximately 300 yards beyond its position in 1890. The most marked advance was in the central portion where the ice current is known to be most rapid. In a footnote it is stated that photographs taken in 1894, show a recession to the position occupied in 1890.

The rate of flow of the ice near the end of Muir glacier, as measured by G. Frederick Wright in 1886, and by Reid in 1890, showed great discrepancies which could not be reconciled. This question which has led to some discussion during the past five years, is briefly considered and the accuracy of the measurements made in 1890 maintained. It will be remembered that the maximum rate of flow in the central portion of the glacier near its terminus, was stated in the report of the expedition of 1890 to be about seven feet per day.

A map of the end of Girdle glacier on a scale of 500 feet to an inch, shows the manner in which it thrusts its extremity into the side of Muir glacier, to which it is tributary, so as to cause the lateral moraines on the main glacier to curve about it in rude semicircles. Stakes were placed along the margin of the expanded terminus of Girdle glacier and their direction and rate of movement measured twenty-four days later. The rate of motion varied from 1.8 to 2.6 inches per day; the direction of movement revealed a spreading of the ice of Girdle glacier, and a slow movement in common with the general flow of Muir glacier. Other instructive facts concerning the unique phenomena revealed by Girdle glacier are recorded. The stakes placed in the ice melted out, but their positions were preserved by placing three small iron plates about each one. The plates, as is the rule with small dark objects lying on the ice, sank into it as melting progressed, and thus maintained their position.

Peculiar holes in the surface of Muir glacier, from a few inches to six or eight feet deep, with a diameter of six to eighteen inches, were found to be due to the lowering of the surface by melting, so as to expose cavities that previously existed in the ice. The holes within

the ice contain water, and are thought to be due to the closing of water-filled crevasses. The presence of water-filled cavities within the ice of glaciers shows that the winter's cold does not penetrate far below the surface.

An ingenious arrangement consisting of two sticks placed in diverging auger holes and inclined toward each other and securely bound together with wire at the surface of the ice, gave accurate measures of the rate of surface melting. In general, the waste on the surface of Muir glacier was two inches per day. Soundings in Muir inlet, which also furnished water samples from various depths, measurements of temperatures for the surface to the bottom, and samples of the bottom, gave a series of instructive records, which are briefly discussed. Tidal observations made in Tidal inlet, a small fiordlike bay, five miles west of the head of Muir inlet, furnished data for establishing a permanent bench mark on the shore by means of which changes of level of the land can be measured. It is hoped that future travelers will repeat these measurements and also profit by the instructions which are given for photographing the extremities of the tide-water glaciers, so that a record of their variations may be obtained.

The report before us contains the records of the only systematic survey that has been made of any of the Alaskan glaciers, and is of special value on account of the painstaking accuracy that characterizes the work. A splendid beginning has been made in the study of the great system of ice drainage that pours into Glacier Bay. It is to be hoped that other students of glacial phenomena, having before them this example of what can be accomplished during a summer vacation, will continue the work and explore the unknown regions surrounding the area represented in Professor Reid's map on every side.

ISRAEL C. RUSSELL.

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*Water Resources of Illinois.* By FRANK LEVERETT; Seventeenth Annual Report U. S. Geological Survey, pp. 695–849, Washington, 1896.

This paper contains much of distinct geological interest, as may well go without saying, both on account of the intimate connection of hydrology with geology, and, in especial, because of the author's thorough study of the Pleistocene formations of the state. The effect of the drift upon topography and drainage is set forth with considerable detail. On the newer drift, within the Shelbyville moraine,

preglacial features are for the most part concealed. The drainage systems are comparatively young, although the streams have the advantage of working on a surface of higher altitude and greater diversity of relief than that of the older drift of central and southern Illinois Streams follow the axes of drift basins included between successive morainic ridges, their longer tributaries being carried on the longer slopes of these basins which lie toward the west and south. A preglacial divide is traced from below Elgin and Lemont to the Indiana state line, and it is highly probable that the headwaters of the Fox, Des Plaines and Kankakee rivers were in preglacial times tributary to the Lake Michigan basin. In northwestern Illinois instances are noted of displacement of the rivers and their beheading by drift deposits. The data supplied by artesian well records suggests several important conclusions as to the deeper strata. The altitudes of the St. Peter sandstone and the base of the Coal Measures are worked out in detail over much of the state. Three thousand feet is considered a liberal estimate for the thickness of the Palæozoic formations of northern Illinois. A maximum of 6000 feet is set for the thickness of the Palæozoic in southern Illinois, of which from 1200 to 1500 feet is allotted to the Coal Measures. The terms Potsdam and Lower Magnesian are retained, and a thickness is assigned to the latter at Rock Island of about 800 feet. In this instance it seems probable to the reviewer that this measure includes the Jordan and Saint Lawrence as well as the Oneota or Lower Magnesian. Remarkable variations in well records are noted, and, like all workers with such data, the author has no doubt felt the embarrassment of riches when more than one well record is extant in any district. At Chicago, for example, the recorded thickness of the St. Peter sandstone ranges from 89 to 420 feet. Surely in the latter measurement the driller, or the authority for the record, has either reckoned in arenaceous beds of the Oneota and the New Richmond, or has been misled by St. Peter sand in drillings far below the lower limit of the formation.

The Potsdam, the St. Peter, the Galena, the Lower Magnesian, and the Niagara, are the chief artesian water-bearing strata.

The author does not find it easy to separate flowing from non-flowing wells in which water rises under hydrostatic pressure, and designates both classes as artesian. He instances wells in Chicago which pass from one class to the other each week, flowing only for a brief period after the Sunday intermission from pumping of neighboring wells.

An interesting fact is the control of artesian head by the height of ground water in the cover area, and several instances are adduced of the head being raised by true influx of surface waters. Under the most favorable conditions the head from the St. Peter and the Galena appears to reach about 675 feet A. T., while from the Potsdam it appears to rise slightly above 700 feet. Few wells in northern Illinois can be depended upon to maintain a head much exceeding 600 feet A. T. A few examples are added to the many on record of local artesian regions whose head is lowered by over draft. In the Chicago district the head of the St. Peter water has been drawn down nearly 100 feet, and this loss of pressure extends ten miles and over west and south of that part of the city where the wells are now numerous. At Joliet heavy pumping of a single well has been found to lower the head several feet in wells nearly one-half mile distant. The increase of mineralization of artesian waters with increase of distance from the area of intake is amply illustrated, sodium chloride, for instance, ranging from about three grains to the gallon at Chicago to about 30 at Rock Island and 277.7 at Barry.

Of less interest to the geologist are the chapters treating of the rainfall, the run off of the streams, and kindred topics. In the chapter on the water supply of the cities and towns, the statement that "the Chicago intakes are affected by sewage only when the Chicago River is at high stages, which seldom amounts to more than a few days each year," is certainly one that does not err from lack of moderation. The final chapter, by Professor J. A. Udden, treats with fullest detail of the artesian district of Rock Island and vicinity. The report is amply illustrated with maps and sections, and it places on permanent record a mass of valuable statistics in several fields. The details, however, are so handled that they do not interfere with the author's direct and luminous treatment of the subject. W. H. NORTON.

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*The Geology of Santa Catalina Island.* By WILLIAM SIDNEY TANGIER SMITH. Proceedings of the California Academy of Sciences, 3d Series, Geology, Vol. I, pp. 1–71, 2 plates and map.

The chief interest in this paper lies in the clear and generally convincing manner in which the author has discussed the physiographic problems presented by his very attractive field; his work being in that respect a continuation of the previous work of Lawson.

Santa Catalina Island is one of the group known as the Channel Islands, and lies about twenty miles off the coast of southern California. Its general trend is northwest by west, with a length of twenty-one miles, and an average width of three miles. It is traversed from end to end by a dominant ridge, culminating at 2100 feet. The general character of the surface is bold and rugged, but it can be differentiated into two topographic types, the one characterized as a young topography, with steep sharp ridges and acute V-shaped canyons, and the other as an older topography, composed of rounded forms, and restricted to the higher portions of the island. In transverse section, the island shows a general slope towards the mainland; the valleys on this side are broad and open, while on the ocean slope they are "long and trough-like." The sea-cliffs, which make up the greater part of the coast line, are in such rapid recession that the narrow V-shaped canyons frequently merely gash their upper fronts, not having been allowed time to cut down to sea level.

A little more than half the island, including most of its western half, is made up of a basement series consisting of quartzite, mica-schists, talc and amphibolite-schists, and serpentine. The eastern portion is mainly occupied by an intrusive mass of porphyrite (in Iddings' sense) with accompanying dioritic dykes, and by andesitic flows of later date. The various intrusive and effusive rocks are described in detail, but present few features of general interest. The occurrence of a small area of rhyolite is noteworthy on account of the few cases in which rocks of this character have been described in the Coast Range region of California. Its age relative to the andesite was not determined. Some small areas of light-colored shale were found on the northeast side of the island, associated with volcanic tuffs, and were correlated with the widespread Miocene shale of the Coast Ranges. In this case the shale is shown to contain over 70 per cent. of opaline silica, and to be made up largely of diatoms and forminifera, as identified by Dr. Hinde.

The serpentines are derived from ultra basic eruptive rocks, and are associated with small amounts of blue-amphibole-schist, the latter probably the result of contact metamorphism.

In a concluding chapter the writer ably sums up the geomorphogeny of the island. Submarine contours show that the Catalina land-mass preserves its form down to a depth of 1800 feet. Near the shore the water deepens rapidly down to 250 feet. At this depth a sub-

marine platform of varying width encircles the island, beyond which the water again deepens. Submarine profiles indicate that the island began its history as an orographic block, tilted to the north, and forming a part of the mainland. It stood 2000 to 3000 feet higher than at present. Following the tilting came the intrusions of porphyrite and diorite. Erosion made considerable progress upon this tilted block, and toward the close of this period the andesitic flows were erupted, accompanied by a slow subsidence. Santa Catalina became an island, depressed, at the close of the downward movement, 1400 to 1600 feet below its present level. During the Miocene a long period of erosion reduced the unsubmerged portions to a peneplain. A gradual elevation of 1850 feet followed, with at least one pause in the movement. The last oscillation is exhibited in the present period of rapid sinking.

The discussion and exposition (very inadequately summarized in a review of this length) is in general admirable. Exception might, however, be taken to the statement, made twice within the paper, that the shortening of a stream's course by the drowning of its lower reaches will cause it to cut down into its alluvial fan.

F. L. RANSOME.

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*Geology of the Castle Mountain Mining District, Montana.* By W. H. WEED and L. V. PIRSSON. Bull. U. S. Geol. Surv., No. 139, pp. 164, 7 plates. Washington, 1896.

Recently considerable study has been directed to the isolated mountains which form the foothills of the Rockies. Such mountain masses offer an inviting field, since they are usually much simpler than the main ranges, and by working out in detail the history of such independent centers of eruption the general order and, perhaps, the causes of differentiation in rock magmas seem likely to be easiest learned.

The Castle Mountain is a dissected volcano, now rising about 3600 feet above the surrounding plain, itself having an altitude of about 5000 feet. The mountain mass is about ten miles in diameter, and stands in central Montana between the Little and Big Belt Mountains. The stratified rocks of the region include representatives of the Algonkian, Cambrian, Silurian, Devonian, Carboniferous, Jurassic, and Cretaceous, preceding the eruption, and certain Neocene lake

beds and glacial drift later than it. The rocks had been folded and eroded before the eruption began, but have been little disturbed since. In general the igneous rocks represent the types resulting from the differentiation of a granitic magma. The more abundant rocks are highly siliceous and rich in alumina and the alkalies. They include granite, granite-porphyry, quartz-porphyry, rhyolite, rhyolitic-obsidian, rhyolitic tuffs and breccias. More basic rocks, including augite-diorite, porphyries, passing into porphyrites, lamprophyric dikes and bosses and basalt flows occur in less abundance. The rocks belong to five groups: (1) The massive plutonic rocks represented by the main mass which is a miraolitic granite becoming porphyritic at the edge, and a second smaller mass, which is dioritic. The latter becomes a quartz-diorite-porphyrite at the edge, and is cut by aplitic dikes, probably from the granite mass. (2) The porphyritic rocks of the intruded sheets and flows include among the acid types micro-granite, quartz-porphyry, granite-porphyry, feldspar-porphyry and porphyrites. The basic types are lamphrophyric rocks, with phenocrysts of mica, augite, hornblende and olivine. Dikes are, upon the whole, rather rare, and in this particular the region stands in sharp contrast with the neighboring Crazy Mountain region. Minettes occur here as intruded masses and sheets rather than in the usual form of dikes. (3) The extrusive rocks include rhyolites and breccias from the granitic mass, and basalts in the region of Volcano Butte. (4) The tuffs and breccias have yielded largely to erosion, as would be expected, and now make up the Smith Lake beds. (5) There are certain igneous rocks in the region which do not seem to belong to this center of eruption. These include a diabase sheet intruded in the Belt shales (Algonkian), and presumably very ancient, certain ash deposits in the Dakota, and certain dikes of porphyrites, acmite-trachytes, trachytes and theralites of Crazy Mountain types.

The general order of eruption seems to have been: first, the diorite (possibly not belonging to the main mass); second, the granite; third, the rhyolite and pitchstone; and, fourth, the basalt and basic dikes. It will be seen that the rocks became successively more highly differentiated. The excellent analyses show that the alkali ratio $K_2O$ : $Na_2O$ is about 1 : 1.55 — 1 : 1.30, with the most rapid variation at the extremes. This ratio is independent of geologic position or coarseness of crystallization, and seems to be characteristic of the magma. A number of interesting petrographical facts are brought out in the

discussion of the rocks. Certain included masses in the granite, apparently resembling those common in orbicular granites, are shown to be fine-grained hornblende-mica-syenite, and it is suggested that their origin may be due to liquation. It is pointed out that the occasional reference of micropegmatitic structure to secondary changes as suggested by Irving, Hobbs, and Romberg, rests upon slight evidence and involves rather violent assumptions as to the method of corrosion.

Aplitic dikes carrying floated fragments of biotite and feldspar similar to the inclusions in the minette dikes at Aschaffenberg were noted. Ilmenite was found altering to leucoxene, which proved to be anatase rather than titanite. A quartz-tourmaline-porphyry is described. The rock occurs as an intruded sheet having a felsitic groundmass, quartz phenocrysts, feldspar flecks, and radial and stellate groups of fibrous tourmaline. It carries fluorite, and is referred to pneumatolitic processes. Among the lamprophyres are augite-vogesites, minettes and monchiquites. The latter are of interest as occurring here in connection with a granitic mass rather than with eleolite-syenite. In connection with this description of the monchiquites is given a note by Kemp correcting an analysis of a similar rock published by him in Bull. U. S. G. S. 107. The basalt carries occasional quartz, but offers no new evidence as to its primary or secondary origin. It is pointed out that the term divitrification, as used in petrography, does not necessarily mean strictly secondary action, since certain spherulites are produced in the process of cooling and while the rock is still viscous. Johnston-Lavis' theory that the variation in rocks is produced by the solvent action of the magma upon the conduit is shown to be untenable so far as this area at least is concerned. The molecular ratio between the alkalies of the most basic and most acid rocks of the series is 125 : 50. This would then require for the production of the latter the solution of at least an equal bulk of rock wholly free from alkali. Furthermore, the acid rocks which, according to the theory, should be first erupted was not first but relatively late. Finally, the dioritic mass, erupted through very basic shales, becomes more acid rather than more basic towards the periphery.

The report is well illustrated, and is of interest, not only from the fact that it deals with a hitherto practically unknown area, but because of the light shed by it upon these more general problems.

H. F. Bain.

*The Ancient Volcanic Rocks of South Mountain, Pennsylvania.* By FLORENCE BASCOM. Bulletin U. S. Geological Survey, 136, Washington, 1896.

When the work on the porphyries of South Mountain was taken up, little was definitely known regarding the occurrence of ancient volcanic rocks in the eastern United States outside of the region in Massachusetts in which certain felsites had been found. Having come across a specimen of the porphyry from South Mountain, Professor G. H. Williams and Miss Bascom visited the region to learn more with regard to its occurrence, and finding unmistakable evidence of the presence of an ancient igneous rock with pronounced flow structure and indications of spherulitic crystallization, it was decided to make a special investigation of the region. This was carried on in the summer of 1892, Professor Williams studying the northern part of the region and Miss Bascom the southern part. The latter also undertook a detailed study of the igneous rocks there found. Preliminary notices of the general geology of these volcanic rocks have been published by Professor Williams, and of the petrography of the most siliceous varieties by Miss Bascom. The present publication presents the complete investigation of all the igneous rocks of the region.

It reviews the literature bearing upon the district from 1755 to 1896. From this it is clear that the true character of the more siliceous rocks was not understood by previous investigators. Three types of rock occur, one a sandstone, conglomerate and quartzite, with occasional argillaceous shale; another an acid volcanic rock, and the third a basic volcanic rock. The sandstone is referred to the Lower Cambrian Age, though not definitely; and the igneous rocks are found to be older than the sandstone, being extrusive lavas overlaid unconformably by the sandstone. They are considered to be of pre-Cambrian Age, and their petrographical resemblance to the Keweenawan volcanic rocks of the Lake Superior region is pointed out. The acid rocks are probably older than the basic ones. But this could not be definitely determined.

Before entering upon the petrographical description of the acid eruptive rocks the author finds it necessary to devote four pages to a discussion of the nomenclature of the aphanitic, porphyritic and non-porphyritic varieties of these rocks—an excellent commentary on the present condition of petrographic terminology. At its conclusion the

author proposes to designate "all acid volcanic rocks the structures of which proves them to have once been glassy, *aporhyolites*, while such as were originally holocrystalline, or whose original character is in doubt, will be termed quartz-porphyries." The prefix *apo* is intended to indicate the fact of a special kind of alteration, namely, that of devitrification of a solid glass. Its application is therefore limited to a certain class of rhyolites, that is, the hyalorhyolites.

The varieties called quartz-porphyry are briefly described, and call for no special comment, except to note the occurrence in them of the unusual mineral piedmontite together with ordinary epidote, both being secondary minerals. The aporhyolites are described at length. They are characterized by numerous spherulites and some lithophysæ, most clearly reorganized on weathered surfaces of the rock. Their form and distribution are the same as in recent, unaltered obsidians. The description of the phenocrysts of feldspar is not entirely satisfactory and their actual character is left in doubt, except that they are undoubtedly alkaline varieties.

The microscopical study of the groundmass has been very thoroughly carried on, and the descriptions make it evident that there once existed in these rocks textures commonly found in modern rhyolites, such as flow-structure, taxitic structure, perlitic cracking and spherulitic crystallization, making it highly probable that these rocks originally solidified in a partially glassy condition. They are at present holocrystalline and exhibit a microcrystalline and also a micropoikilitic texture. The latter is discussed at great length and its secondary character in these rocks is clearly established. The author recognizes the fact that the same or a similar texture is also a primary crystallization in certain other rocks. Flow-breccias and tuft-breccias are found in connection with the massive lavas. In places the massive rock is metamorphosed into a sericite-schist, in which often the original phenocrysts are still preserved. The chemical compositions of the two rocks are nearly identical.

The petrographical description of the basic eruptives begins with a discussion of the nomenclature relative to these rocks, which is short and leaves the subject in a confused condition; the confusion being carried throughout the chapter. The confusion is based on the conclusions arrived at in the paper by Professor W. S. Bayley, which is quoted by the author. The mistake is made in assuming that the definition of the groups within the gabbro class of rocks as suggested

by Professor Bayley is final, or even that it is acceptable to the majority of petrologists. So far as a distinction between gabbro and diabase is made to rest on purely textural grounds, one being granular and the other ophitic, Professor Bayley's conclusions are good, but the effort to relate these textures to the mode of occurrence of the rock, as intrusive or extrusive, is futile, and the suggestion that the term diabase be applied to holocrystalline extrusive lavas having the composition of gabbro, and the term basalt to those that are hypocrystalline (partly glassy) is wholly impracticable. Throughout the chapter the terms melaphyre, augite-porphyrite and diabase are used as synonyms. It does not appear from the description in what sense the term augite-porphyrite is to be understood, since the structure and mineral constituents of these basic rocks at South Mountain are said to be markedly uniform (*op. cit.* p. 72.); the texture is micro-ophitic and the porphyritic structure is inconspicuous, the largest feldspars being $0.8^{mm}$ long. Since it is not possible to prove that the original lavas were or were not glassy, they are classed as having been originally crystalline and for this reason are called diabase in the sense suggested by Professor Bayley. The term apo-basalt could not have been used without question.

Although the rocks have been greatly altered, enough of their original texture has been preserved to render their identification satisfactory. They had the mineral composition and texture found in many recent basalts. In some cases olivine still remains, in others its outline only is left. In some cases lime-soda-feldspar, augite and magnetite still exist. The secondary minerals formed are quartz, epidote, actinolite, chlorite, and leuxocene. Their relative proportions vary in different places. With very complete change in mineral composition there is surprisingly little change in the texture of the rocks. The chemical analyses of the altered rock shows considerable divergence in some constituents from the composition of normal basalts. Amygdaloidal, brecciated and tuffaceous forms of the rock occur, which clearly indicate the extrusive character of the lavas. The amygdaloidal varieties have been specially liable to metamorphism, resulting in schists, or slates, spotted where the former amygdales have been dragged into flattened disks.

The bulletin closes with a summary of the facts and conclusions regarding the occurrence and nature of the rocks, and with a brief notice of the occurrences of similar ancient volcanic rocks in North

America, and also with a valuable list of papers in which points of resemblance between ancient and modern acid volcanic rocks have been emphasized, and those treating of devitrification and of spherulites. The paper is well illustrated by twenty-eight plates and is a valuable contribution to our knowledge of ancient and more or less metamorphosed volcanic rocks.

The restriction of the prefix apo to those altered rocks that originally contained glass, leaves unsatisfied the demand for a general term which can be applied to all more or less metamorphosed lavas that once corresponded to unaltered rhyolites, basalts, andesites, etc., whether glassy or holocrystalline. In this case it would seem advisable to adopt the prefix eo, proposed by Nordenskjold[1] without regard to any particular age, indicating simply that the altered rock had originally been what the remainder of the term signifies. In this sense the volcanic rocks of South Mountain might be called eorhyolites and eobasalts.

J. P. IDDINGS.

[1] *Ueber archæische Ergussgesteine aus Småland.* Bull. Geol. Instit., Upsala, No. 2., Vol I., 1893.

# ABSTRACTS.

*Upper Cretaceous of the Northern Atlantic Coastal Plain.* By WM. B. CLARK.

This paper was prepared in coöperation with Messrs. R. M. Bagg and Geo. B. Shattuck who have been Professor Clark's geological assistants for several years. The authors divide the upper Cretaceous into (1) the Matawan formation (including the Crosswicks clays and Hazle, sands), (2) the Monmouth formation (including the Mount Laurel sands, the Navesink marls, and the Redbank sands), (3) the Rancocas formation (including the Sewell marls and Vincentown lime sands), (4) the Manasquan formation. Conformably overlying the last and probably of Eocene Age is the Shark River formation. The areal distribution of these five formations was represented upon a large map on the scale of one mile to the inch, which embraced the area between New York Bay and the Potomac River. The variations in distribution and structural relations presented throughout this distance of over 200 miles were discussed as well as the faunal characters of the several formations. The unconformity existing between the lowest of the Cretaceous formations and the Potomac formation below was pointed out as well as the clearly defined unconformity of the Miocene upon the uppermost member of the green sand series; at the same time the evidence for and against unconformity between the Monmouth and Rancocas formations was discussed without a final decision being rendered upon this point, the evidence being somewhat conflicting in this matter. The Matawan-Monmouth formation was held to be equivalent to the Eutaw, Rotten Limestone and Ripley groups of Alabama and the Pamunkey formation equivalent in all probability to all or the greater part of the Lignitic, Buhrstone and Claiborne of the same area, so that the Rancocas, Manasquan and Shark River formations must represent the interval between the Ripley and Lignitic of the Gulf. The first two are regarded as of Cretaceous, the last of Eocene Age. The different Cretaceous formations of the Atlantic coastal plain were shown to be approximately equivalent to the Senonian and Danian of Europe.

*Age of the Lower Coals of Henry County, Missouri.* By DAVID WHITE.

Under this title was presented a discussion of the evidence derived from extensive collections of fossil plants as to the stage of those coals in other American and European sections. Although the stratigraphic palæobotany of the Pennsylvania–Ohio bituminous series is but very imperfectly known, the indicated position of the basal coals of Henry county is apparently higher than the Mazon Creek stage or Brookville and Clarion coals, and presumably lower than the Middle Kittanning, it being perhaps near the Lower Kittanning in that series. Compared with the plants from the section of the Northern anthracite field the Missouri flora is considered by Mr. White as hardly so recent as the E ("Pittston" or "Big") vein though probably as late as the D ("Marcy") vein with which it seems to be nearly synchronous.

Concerning the relations of the Missouri flora to the floras of the Old World, to which forty-two of the forty-four American genera are common, the conclusions are very interesting if, as the author maintains, the occurrence of the same species in the different basins was approximately contemporaneous. The comparative study of the geographical and the vertical distribution of the species from the basal coals of Henry county shows that this flora is probably later than the Middle Coal Measures of Great Britain, the closest alliance being with that found in the "transition series" between the Middle Coal Measures and the Upper Coal Measures, with the flora of which ours has much in common. A similar strikingly intimate relationship, involving a large percentage of identical species, exists between the Henry county flora and that of the Valenciennes series (*Houiller Moyen*) in the Franco-Belgian field. The American flora is clearly not older than the third or upper zone of this series, to which M. Zeiller would also refer our Mazon Creek plants. The correlative conclusions respecting the British and the Franco-Belgian measures are corroborated by the relations of our flora to the plants of the Geislautern beds, which shows that the stage of the Missouri plants is in the upper part, probably near the top of the *Sarrbrücker Schichten* (Westphalian).

The local stratigraphic position of the phytiferous beds of Henry county, the Jordan coal, and another seam about forty-five feet higher, is, as described in the state reports, somewhat peculiar, since these beds lie, at some points, in almost direct contact with the deeply eroded floor of Mississippian rocks. The plants offer therefore criteria by which to approximately fix the date when the early Meso-Carboniferous

inundation reached the vicinity of Clinton, and they mark the close for that district, of the post-Mississippian erosion period, during which the entire Pottsville series, reaching at some points a thickness of two thousand feet or more, and a portion of the Lower Productive Coal Measures were laid down in the Appalachian basin.

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*Crater Lake, Oregon.*[1] By J. S. DILLER.

Crater Lake of southern Oregon is deeply set in the hollow base of a large cone upon the summit of the Cascade range. Its rim rises by moderate slopes a thousand feet above the general level of the range, and the descent within to the lake is precipitous. The lake, with an altitude of 6239 feet above the sea, has no outlet. It is approximately circular, with an average diameter of about five miles, and is completely surrounded by cliffs ranging from over 500 to nearly 2000 feet in height. The steep slopes continue beneath the water to a depth of 2000 feet. The great feature of the region is not the lake, but the caldera which it half fills and thus partly conceals but greatly beautifies. The rim has the structure of the peripheral portion of the base of a great volcano. It is composed of lava streams and sheets of volcanic conglomerate radiating from the lake. Sections of the coulées appear upon the inner slope of the rim where their broken ends form cliffs toward the lake, and it is evident that they once converged, forming a large volcano on the site of the lake, from which they issued. In some cases, as for example under Llao Rock, the valleys filled by great flows upon the outer slope of the central volcano are clearly visible in the section afforded by the rim. The earlier lavas of the rim are andesites, and the later ones rhyolites, while basalts, which are also of late eruption, are confined to small adnate cones low down upon the outer slope of the rim. The rim is cut at a number of points by dikes radiating from the lake, and this feature taken in connection with the succession of lavas, and especially the structure of the rim, clearly points to Crater Lake as a great volcanic center. The rim of the lake has been deeply scored by glaciers, but this phenomena is confined wholly to the outer slope. Striæ and moraines are found on the very crest of the rim overlooking the lake. Deep U-shaped canyons extend directly through the rim ending on

[1] Published in the American Journal of Science for March 1897, and in a more popular form in the National Geographic Magazine for February 1897.

the brow of the cliff which rises many hundreds of feet above the lake level. All of these features must have been formed by glaciers descending from the peak represented by the rim. In other words, during the glacial period Crater Lake did not exist, but in its place there towered a great volcanic peak, rivaling Shasta in size, from which emanated the coulees of the rim as well as the glaciers for its striation. The relation of the striæ to the later flows shows that the volcano was yet active in the glacial period. The removal of so great a volcano and the production of the large caldera is due to subsidence. This is shown by the absence of a fragmental rim, such as would have been formed if the material had been removed by an explosion, and also by the action of the final coulée from the volcano. It flowed not only over the outer slope of the rim, but also over the inner slope toward the abyss into which the mountain disappeared. Since this engulfment several smaller piles of volcanic material have been formed by eruptions upon the bottom of the caldera. One of these rises so high as to form an island in the lake, and furnishes an excellent example of a cinder cone and lava field.

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*Nipissing-Mattawa River, the Outlet of the Nipissing Great Lakes.* By F. B. TAYLOR.

When the waters of lakes Superior, Michigan and Huron were making the Nipissing beach, their outlet was eastward over the Nipissing pass at North Bay, Ontario, to the Ottawa valley. This outlet river is called the Nipissing–Mattawa River and the three upper Great Lakes of that time are called the Nipissing Great Lakes. Mr. G. K. Gilbert visited North Bay in 1887, Professor G. F. Wright in 1892 and the writer explored some of the ground at North Bay in 1893, and more, with a visit to Mattawa, in 1895. Last autumn a canoe trip of six days in fine weather was made from the head of Trout Lake to Mattawa, thus covering the whole length of the Mattawa valley.

The Nipissing beach is well developed at North Bay at an altitude of about 700 feet above sea level. On the present col at North Bay the old outlet bed is somewhat over a mile wide, 30 to 35 feet deep at the maximum and perhaps half that on the average. The average here, however, is not easy to get, for there was an archipelago on the south side, and not much is known as to the number and capacity of the old channels between the islands. The first swift water of the ancient

outlet was at the foot or east end of Trout Lake about twelve miles east of North Bay. The Nipissing beach though faint can be followed to the foot of Trout Lake.

The effects of the flowing current of the ancient outlet river are well marked at several points. The places of several ancient rapids and one cataract were found. The cataract was at the present Talon Chute and the four most notable rapids were, (1) below Turtle Lake, (2) below a lake called Pimisi Bay, (3) at the modern Des Epines Rapids and (4) at Mattawa. The falls were 25 to 30 feet high and the postglacial gorge made by them is very distinct. It is not quite half a mile long, but it is deep and averages only about 300 feet in width. The walls are of red granite and vertical 40 to 100 feet. A thin and highly inclined bed of crystalline limestone passing down into the gorge from the west may have hastened the cutting somewhat. The ancient river was expanded to a lake in the Lake Talon basin, and made faint but distinct shore lines by wave action. One is 20 feet above the present lake and the other ten or twelve feet higher. The mark of the surface level of the river was quite plain at some of the rapids. On the north side at Des Epines rapids this mark is 55 feet above the present river. The channel at that level was between 600 and 700 feet wide and averaged 35 to 40 feet in depth, and the current was strong enough to move gravel and pebbles of small size. This corresponds in a general way with the size of the modern St. Clair River.

Ancient rapids were recognized in three ways. There are several narrow passages that are heavily bowlder-paved. They mark the points where moraines cross the channel. At Des Epines and Mattawa the bowlders of gneiss and granite are worn and scoured into many curious forms. Many were found with basins or potholes bored in them and a few bored clear through so as to become ring-bowlders. At each of these rapids a stream enters just above and furnished a constant supply of gravel, sand and pebbles for the current to roll over and among the bowlders. The rapids below Turtle Lake and Pimisi Bay are of the same sort except that the water issued from lakes, and so had no supply of gravel to scour with. The third way of recognizing rapids was by inference indirectly. Such rapids were in narrow defiles or canyons with walls of bare rock and the fact that rapids had existed there was inferred from the observed drop in the surface level of the river above and below. The remains of the ancient Nipissing–Mattawa River agree with the Nipissing beach in indicating that

the Nipissing Great Lakes endured for a relatively long period of time. And so long as it lasted, Niagara had only the discharge of Lake Erie.

A detailed account of the scoured bowlders appears in the current (March) number of the *American Journal of Science*.

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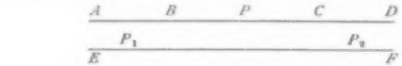
*The Grain of Rocks.* By ALFRED C. LANE.

The grain of rocks is dependent on the chemical composition and the causes that produce solidification, cooling, gas diffusion, etc., the general law being, the more rapid the action the finer the grain. The paper discusses the grain from the threefold standpoint of theory, observation upon the Keweenawan rocks, and experiment.

In regard to chemical composition, the augite of the luster-mottled melaphyres shows plainly the empirical law that the less there is of it the finer is its grain, other things being equal.

The following laws of cooling are mathematically applicable to an indefinite sheet:

(*A*) The case where we consider the adjacent rock symmetrically heated by the sheet can be solved by aid of a solution for the case that the walls are kept at a fixed temperature. For the temperature at any point *P* of the affected zone *A D* (the sheet and its contact zone) is the average of the temperatures that two points $P_1$ and $P_2$ would have that were at the same distances from the walls of a hypothetical dike *E F*, as broad as the whole zone affected (its walls being kept at a constant temperature) as the point whose temperature is sought is from the two walls of the smaller sheet; the sum of the temperatures being




taken if said point is within the small dike, the difference if it is outside in the contact zone (time and initial conditions being the same).

(*B*) Taking the case of a sheet originally of a uniform temperature where the sides of the sheet are kept at a fixed temperature, we can divide the cooling into three periods:

(1) Before the center has cooled appreciably. During this period the rate of cooling is as the square of the distance of the margin, and independent of the size of the sheet otherwise.

The augite of the Keweenawan ophites follows in its grain this law, the average area of cross sections being proportional to the square of the distance from the margin, and independent of the size of flow.

Consolidation in this period may *a priori* be expected to be especially characteristic of effusive and porphyritic rocks.

(2) While the center is cooling down one-fourth of original difference in temperature between sheet and margin. This period is about four times as long as the first.

(3) Thereafter the rate of cooling when given temperature is reached will be independent of the position of a point. Hence the grain will be uniform and the same for all parts of the sheet that consolidate in this period. The solidification will tend to fall into this period for high initial temperatures of the magma and hot walls, compared with the temperature of solidification and broad contact zones. Hence solidification in this period may be taken as typical for abyssal rocks.

Dikes of the Keweenawan in the Huronian show a marginal zone where the grain appears to have been formed in the first period of solidification, and a central belt where the solidification appears to have been in the third period.

Similar phenomena may be reproduced in melted sulphur, and in sugar and water. In the latter case we have phenomena of aqueo-igneous fusion, and the temperature of solidification being comparatively low, there is a strong tendency toward the appearance of the central zone of uniform grain. The tendency to solidify as glass is dependent upon the escape of the water.

If the sides are not kept at a fixed temperature, the sides will cool more slowly than the center, for temperatures half way between the initial temperatures,—a possible explanation lies here for a certain kind of porphyritic facies of granites.

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*A Study of the Nature, Structure, and Phylogeny of Dæmonelix.* By E. H. BARBOUR.

Additional expeditions to the Dæmonelix region have added new data showing the apparent steps in the phylogeny of this anomalous group.

The simplest expression of Dæmonelix seems to be a fiber found in the sand rock, which shows unmistakable plant structure, and is, in every respect, like the fiber found in all the Dæmonelix series. The author's present belief is that the various forms of the Dæmonelix group result from the aggregation of these simple fibrous, fresh-water seaweeds into variously shaped bunches, clusters, and spirals.

Ascending to higher beds one comes next to Dæmonelix "cakes," which are about the size of common camp griddle-cakes. So far as can be determined by the eye or the microscope they are nothing more nor less than colonies, or aggregations of Dæmonelix fibers. Vertical range twenty-five feet.

Next above the "cakes" come the Dæmonelix "balls," which resemble in size and shape the old New England codfish ball. These are but aggregations or bunches of Dæmonelix fibers. Vertical range about twenty-five feet.

Next come slender forms of nearly vertical and somewhat spiral habit, called Dæmonelix "cigars." The weathered and broken ends of these occur in immense abundance. They are about the size and length of an ordinary walking stick. These, too, are but aggregations of the simple Dæmonelix fiber. Though practically confined to a range of twenty nor more feet they occur, in decreasing numbers, almost through the upper Dæmonelix beds.

The forms encountered next are frail and slender, scarcely thicker than the wrist, yet positively spiral and vertical in habit. They are viewed as the immediate progenitors of Dæmonelix regular. They are but aggregations of the primitive Dæmonelix fiber. Vertical range scarcely twenty feet.

Above all, comes the "Devil's Corkscrew," the first forms of which are smaller, more regular, and more mathematically exact than are the larger and strangely modified forms characteristic of the topmost beds. Some are free spirals, some are fixed about an axis, some have no transverse trunk, others have one, two, or three; others, called "twin screws," have, in each case, a large screw and transverse trunk, ending in a smaller reversed screw and trunk. These are thought to be the first complete specimens of Dæmonelix. Continued study makes it only the more apparent that these magnificent screws are but spiral aggregations of the simple Dæmonelix fiber first encountered.

More than one hundred micro-sections have been cut from all parts of all forms. Without exception all show precisely the same simple, cellular, non-vascular structure, to be likened only to sea-weed. Numerous photomicrographs of these have been made and are ready for publication.

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